AD-765 363

PRINCIPALS OF RADAR AND METEOROLOGICAL RADAR DEVICES

Oleg G. Korol, et al

Army Foreign Science and Technology Center
Charlottesville, Virginia

19 June 1973

FSTC-HT-23-149-73
19 June 1973

ARMY MATERIEL COMMAND

U.S. ARMY
FOREIGN SCIENCE AND TECHNOLOGY CENTER

AD 765363

PRINCIPALS OF RADAR AND METEROLOGICAL RADAR DEVICES

by
O. G. Korol' and
R. D. Chernyak

USSR

This document is a rendition of the original foreign text without any analytical or editorial comment.

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SI-73-534 487

134

TECHNICAL TRANSLATION

FSTC-HT-23- 149-73

ENGLISH TITLE: Principals of Radar and Meteorological Radar Devices

FOREIGN TITLE:

AUTHOR: O. G. Korol' and R. D. Chernyak

SOURCE: Leningrad: Gidrometeorologicheskoye idzatel'stvo, 1971, pp. 214-330 (chapters 8, 9, and 10)

GRAPHICS NOT REPRODUCIBLE

Translated for FSTC by LEO KANNER ASSOCIATES

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Foreign Science and Technology Center
US Army Materiel Command
Department of the Army

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE

Principles of Radar and Meterological Radar Devices

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Translation

5. AUTHOR(S) (First name, middle initial, last name)

Oleg G. Korol', Rim D. Chernyak

6. REPORT DATE
19 June 1973

7a. TOTAL NO. OF PAGES
130

7b. NO. OF REFS
N/A

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c. T702301 2301

d. Requestor: C. E. Foster

9a. ORIGINATOR'S REPORT NUMBER(S)

FSTC-HT-23-149-73

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
US Army Foreign Science and Technology Center

13. ABSTRACT

Three meteorological radar units are described: the Malachite radiotheodolite with rangefinder attachment, the Meteorite radar station, and the MRL radar station. The principles of operation of these systems are given along with circuit descriptions and explanations of the operation of the individual units within each system.

The Malachite and rangefinder are used in conjunction with the A-35-1P transmitter/transponder and/or the A-22 radiosonde in the v.h.f. range. When these units are sent aloft together, the radiotheodolite determines elevation, azimuth, and slant range, as well as the pressure, temperature, and humidity data transmitted by the A-22. When the A-35-1P is sent up alone, the radiotheodolite determines only the angle coordinates. The circuit and operation of the A-35-1P is described.

The Meteorite radar station operates in the centimeter range and is used to track radiosondes of the RKZ type as well as corner reflectors; provision is made for automatic tracking. A single radio channel is used to transmit the f.m. signals of the meteorological elements and the range signals. The circuit and operation of the RKZ-2 is also described.

The MRL radar station, which is also a centimeter station, is a new system being used by the hydrometeorological services in the USSR to detect, observe, and determine the location of thunderstorm and shower cells. It is produced in two versions, a portable two-channel set (MRL-1), whose second channel operates in the millimeter range, and a stationary single-channel set (MRL-2).

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Meteorologic Radar						
Radar System						
Range Finder						
Radiosonde						
Radar Station						
Radar Technology						
Range Finder						
Radar Component						
Theodolite						
Radar Antenna						
Radar Tracking						
Ppi Scope						
Atmospheri Cloud						
Cosati Subject Code: 17; 4						
Country Code: UR						

UNCLASSIFIED
Security Classification

Chapter 8

The "Malachite" Radiotheodolite with Rangefinder Attachment

The system consisting of the Malachite radiotheodolite, a rangefinder attachment, and the A-22 radiosonde is designed for finding wind speed and direction and also for obtaining information about the quantities of meteorological elements to an altitude of 40-50 km. Like any radiosonde observation system, it is a radio location and telemetric system.[1]

An A-35-1P radio transmitter/transponder, whose frequency is 216 MHz, is set into free flight under a hydrogen-filled balloon along with the A-22 radiosonde or by itself (the A-35-1P transmitter schematic is considered in Section 8.7 of this chapter). In the first case the Malachite radiotheodolite determines the angle of elevation, the azimuth, and the slant range of the radiosonde and also provides for reception of the radiosonde audio signals, which are used to determine pressure, temperature, and humidity at various altitudes.

This method is called <u>complex temperature-wind sounding of the atmosphere</u>.

In the second case, when the transmitter/transponder is set into flight without the radiosonde, the radiotheodolite determines only the coordinates, which are used to determine wind speed and direction at different levels.

This is the <u>radiopilot</u> method.

The advantage of the Malachite radiotheodolite is its simplicity of construction, and its shortcomings are the low level of precision in determining the angle coordinates and the slant range, as well as the lack of automatic tracking of the radiosonde. Moreover, the working range along the vertical angle (the angle of elevation) lies within the limits 16°-75°, which significantly reduces the usefulness of observations made with the Malachite radiotheodolite.

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[1] This system is an improved version of the direction finding system used in the fifties with the GUGMS aerological network.

BASIC TACTICAL AND TECHNICAL SPECIFICATIONS

1.	Range of operation	not less than 100 km.
2.	Radiotheodolite frequency range	215-218 MHz
3.	Radiation pattern bandwidth at 0.7 E_{max} level	18°
4.	Inquiry pulse repetition frequency of transmitter, f_3	1070 p/s
5.	Duration of inquiry pulse, t_i	2 μsec.
6.	Transmitter power in pulse, P_i	30 kw.
7.	Receiver sensitivity for $V_s/V_n = 2$	not worse than 8 μv.
8.	Rotation frequency of the radiation pattern	50 Hz
9.	Maximum error in determining elevation within working range	no more than 1.6°
10.	Maximum error in determining azimuth in 0-360° range	no more than 1.6°
11.	Error in measuring distance up to 100 km.	±50 m.
12.	Error in measuring distance from 100 to 200 km.	±75 m.
13.	Power supply: 127-220 v. at 50 Hz	
14.	Power consumption	2.4 kw.

The Malachite radiotheodolite antenna system receives pulse signals from the radiosonde transmitter/transponder, whose duration and repetition frequency depend on the position of the commutator of the radiosonde. There are two pulse repetition frequency ranges, a low-frequency range (300-2300 Hz), which is used for transmitting the meteorological information (pressure, temperature, humidity), and a high-frequency range (over 2900 Hz). The high repetition frequency (signal-pause) is used for determining the distance to the radiosonde and also for direction finding in the absence of signals carrying meteorological information.

The angle of elevation and the azimuth of the transmitter being tracked are determined by the bi-signal zone method. The radiotheodolite radiation pattern is shifted in space and occupies positions in this order: left, upper, right, lower. The left and right positions of the radiation pattern form a bi-signal zone along the azimuth, and the upper and lower positions form a bi-signal zone along the angle of elevation. Two pairs of pulses (Fig. 8.1) are visible on the Malachite angle-coordinate indicator, which allows taking a bearing from two coordinates simultaneously on one screen.

If the target direction is congruent with the line passing through the origin of the radiation pattern and the point of intersection of the pattern along each coordinate, the pulse amplitude on the indicator will be the same.

The slant range from the sounding station to the radiosonde transmitter is determined by the method of secondary radiolocation. The transmitter of the rangefinder attachment emits a powerful inquiry pulse in the direction of the drifting radiosonde. After the inquiry pulse operates on it the transponder sends an answering signal which is picked up by the radiotheodolite antenna. This signal appears on the range indicator as a bunch of pulses whose brightness and amplitude are greater than the brightness and amplitude of the noise path. The slant range to the radiosonde is determined by matching the answering signal with the electronic hairline. The range indicator has two sweeps, coarse and fine. At the coarse sweep a bright mark (the 3-km. gate) serves as the electronic hairline, and at the fine sweep a dark mark (the narrow gate) is the hairline. As soon as the answering signal appears on the indicator the range mechanism is used to match the signal with the bright mark at the coarse sweep, and then the leading edge of the answering signal is matched with the dark mark at the fine sweep. At this moment the slant range is read off the scale.

To increase precision in the reading, the entire range distance (200 km.) is divided into ranges of 20 km each (0-20, 20-40 km., etc.). A switch selects the range in proportion to the distance of the radiosonde from the transmission point.

In processing the data of the ascent of the radiosonde, the slant range is used for finding the altitude of the radiosonde:

$$H = R_s \sin \beta \tag{8.1}$$

where β is the angle of elevation.

In the radiotheodolite receiver (in the sound channel) the low-frequency pulses (meteorological information) are amplified and the high-frequency pulses (the pauses between code signals) are attenuated.

For recording the radiosonde signals the output of the Malachite receiver is connected to a PR-16 automatic recorder. The audio signals of the radiosonde can be heard with headphones.

A functional diagram of the Malachite radiotheodolite with rangefinder attachment is shown in Fig. 8.2. In operation the transmitter, receiver, angle-coordinate indicator and slant-range indicator are synchronized by pulses developed in the trigger unit.

Signals carrying meteorological information are picked up by the radiotheodolite antenna system and fed through the high-frequency (h.f.) section of the antenna commutator and the h.f. slip ring to the receiver input. From the low-frequency receiver output the signals go to headphones and the line connecting the radiotheodolite and the radiosonde observation point. The video pulses go from the receiver to the angle-coordinate indicator.

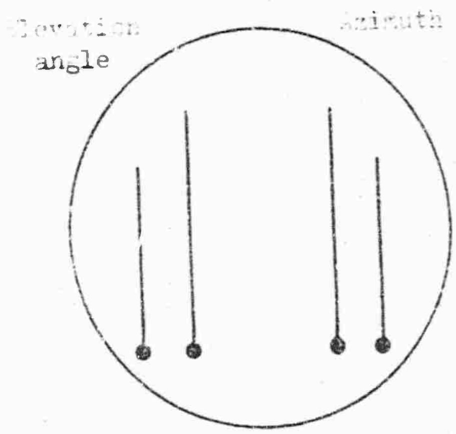

Fig. 8.1. Video pulses on the angle-coordinate indicator

The low-frequency section of the antenna commutator and the control voltage generator (CVG) together develop the voltage for controlling the operation of the angle-coordinate indicator. The control voltage is used to form the video-pulse sweep voltage and the voltage that cuts off the electron beam when the radiation pattern switches from one position to another.

The synchronization pulses coming from the trigger unit to the transmitter trigger the h.f. oscillator. The inquiry pulses travel along coaxial cable through the h.f. slip ring of the transmitter to the transmitting antenna of the radiotheodolite, which is positioned in the center of the receiving antenna system.

As high-frequency pulses are generated, the inputs of the angle-coordinate indicator and the receiver are fed suppressor pulses from the trigger unit which block these units and protect them from the powerful inquiry pulse.

The inquiry pulse from the transmitter antenna actuates the radiosonde transmitter/transponder, which makes an answering pulse corresponding in time with the inquiry pulse but at an amplitude 10-20% greater than usual. The answering pulse reaches the receiving antennas of the radiotheodolite and travels through the h.f. section of the antenna commutator and the receiver, and from the receiver output is fed to the range indicator.

The units of the radiotheodolite and the rangefinder attachment function as follows.

1. The antenna feeder system creates a radiation pattern, emits

the transmitter pulses, and receives the signals from the radiosonde. Since there is no antenna switch in the Malachite, a pulse from the trigger unit blocks the receiver when the transmitter is in operation.

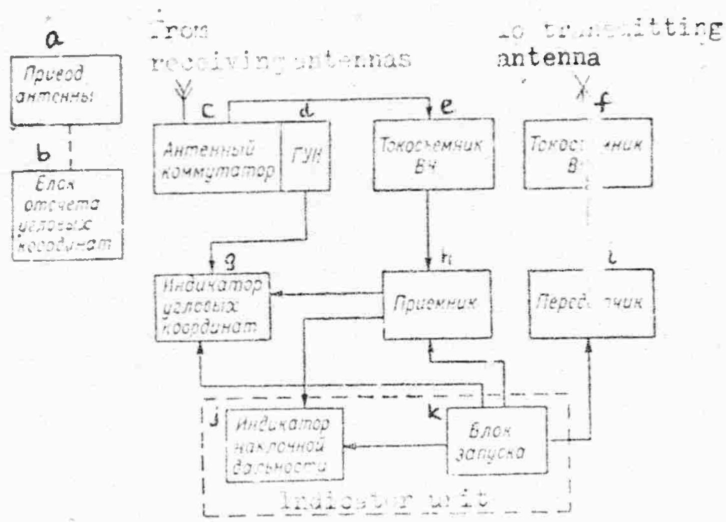

Fig. 8.2. Functional diagram of the radiotheodolite

Key: a. Antenna drive
b. Angle-coordinate reading unit
c. Antenna commutator
d. CVG
e. H.f. slip ring
f. H.f. slip ring
g. Angle-coordinate indicator
h. Receiver
i. Transmitter
j. Slant-range indicator
k. Trigger unit

2. The transmitter is designed to generate powerful inquiry pulses with a repetition frequency of 1070 p/sec. and a duration of 2 µsec.

3. The receiver amplifies the radiosonde signals picked up by the antenna, converts the pulses, and distributes these pulses to the range- and angle-coordinate indicator channel and the channel for the audio reception of pressure, temperature, and humidity data.

4. In the "Operate" mode the angle-coordinate indicator is designed to determine the bearing with respect to elevation and azimuth from video signals on the cathode ray tube. In the "Check" mode the pulse shape of the radiosonde transmitter can be examined on the indicator's screen, i.e., the indicator functions as an oscillograph.

5. The indicator unit, which includes the slant-range indicator and the trigger unit, provides for visually observing (on the c.r.t. screen) the radiosonde transmitter answering pulse, for matching it with the electronic hairline and reading the slant range, and for synchronizing the operation of the whole station.

6. The angle-coor inate reading unit, in which the selsyn receivers are housed, is designed for reading the elevation and azimuth at the moment the bearing is taken.

7. The power supply system provides all units of the radiotheodolite and rangefinder attachment with the voltages necessary for normal operation.

8.1. The Antenna Feeder System

The antenna feeder system of the Malachite radiotheodolite (Fig. 8.3) consists of four receiving director antennas 1 and one transmitting antenna 2, high-frequency feed cables 5 (feeders) connecting the antennas to the receiver and transmitter, four adjusters 4 (only in the receiving wave channels), a phasing system 6 with antenna commutator 7, and two h.f. slip rings 8 (for the transmitter and the receiver). A balun is used in each channel to connect the center-fed dipoles of the antenna to the coaxial feed cable.

The specifications for the AFS are as follows.

1. It operates in the 215-218 MHz range with a basic tuned frequency of 216 MHz.

2. When a bi-signal zone is formed, the intersection level of the radiation patterns at the extreme positions is at least 75% of E_{max} (Fig. 8.4).

3. The size of the minor lobes of the radiation pattern is not more than 25% in terms of voltage.

4. The traveling-wave ratio in the feedline is not below 0.5.

The receiving antennas constitute a system of four director antennas (two along the elevation angle and two along the azimuth) in order to increase the front-to-back ratio, create a bi-signal zone, and obtain the required radiation pattern bandwidth.

The adjusters are segments of rigid coaxial line that are included in the antenna feeder circuit; they are used to match the electrical and geometric axes of the antenna.

The phasing system together with the high-frequency section of the antenna commutator is designed to change the position of the radiation pattern in space, i.e., to create a bi-signal zone in the vertical and horizontal planes.

The low-frequency section of the antenna commutator together with the control voltage generator provides the voltage that controls the operation of the angle-coordinate indicator, i.e., it creates the sweep and quench voltages for the electron beam.

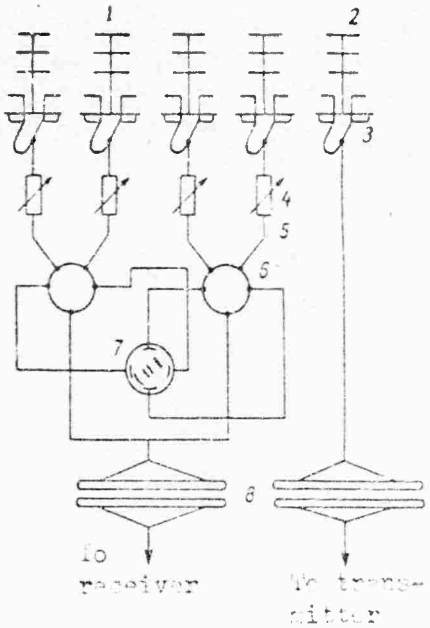

Fig. 8.3. Antenna feeder system

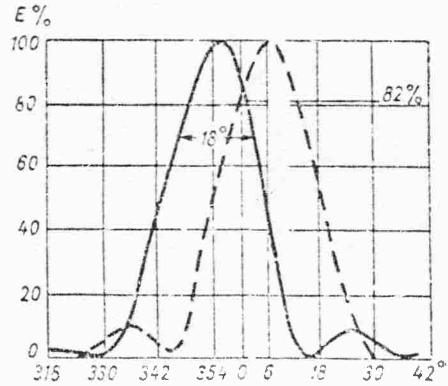

Fig. 8.4. Intersection of the radiation patterns

The high-frequency slip rings are designed to transmit h.f. energy from the receiving antennas to the receiver or from the transmitter to the antenna.

8.2. The Transmitter

The transmitter of the metric distance rangefinder attachment operates in a pulse mode and is used to find the slant range of the radiosonde.

The transmitting circuit consists of a submodulator, a modulator (power amplifier), and an ultrashort-wave oscillator. The block diagram of the transmitter is shown in Fig. 8.5. Since the transmitter works in a pulse mode, slant range is determined by the time between the beginning of the transmitter emission of the inquiry pulse and the reception of the answering pulse. A 75-kHz crystal-controlled sine wave oscillator is used to precisely determine this time. The crystal oscillator is located in the trigger unit and controls the operation of the transmitter.

Let us examine the transmitter circuit, shown in Fig. 8.6. Synchronization pulses coming from the trigger unit at a frequency of 1070 Hz (obtained by dividing the 75-kHz frequency), a duration of 1 μsec., and an amplitude of 150 v. go through the winding of transformer T1 to the screen grid of V1. The blocking oscillator assembled at V1 functions as the submodulator. The value of R3 is selected so that the tube does not cut off and the blocking oscillator generates pulses

with a low repetition frequency (50 Hz).[1]

The blocking oscillator control-grid circuit includes an open-end artificial forming line, which stabilizes the duration of the generated pulses at 2 μsec. From the output winding of pulse transformer T1 positive 1200-v. pulses are applied to the screen and control grids of V2 and V3 (GMI-83's), which are the load of the blocking oscillator.

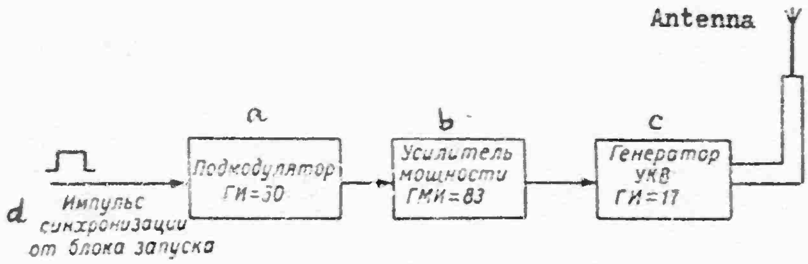

Fig. 8.5. Block diagram of the transmitter

Key: a. Submodulator (GI-30)
b. Power amplifier (GMI-83)
c. U.s.w. oscillator (GI-17)
d. Synchronization pulse from trigger unit

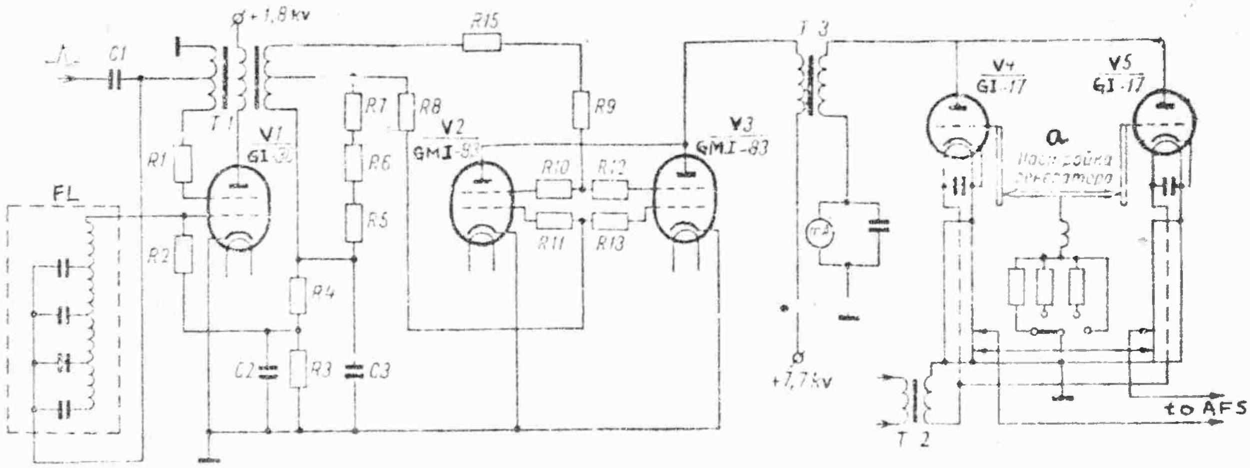

Fig. 8.6. Basic circuit of the transmitter

Key: a. Oscillator tuning

The modulator is assembled in two tubes connected in parallel as a power amplifier with pulse transformer T3 in the plate circuit.

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[1] This mode of operation of the blocking oscillator corresponds to the mode of external synchronization described in Chapter 3.

Automatic bias formed by the grid currents is used to cut off the tubes in the intervals between pulses. A 100-v. bias is applied to the control grid of the tubes through resistors R3 and R4. This voltage is sufficient to cut off the modulator tubes, since the screen-grid pulse supply coming from the modulator is used. This circuit prevents a large negative voltage from being fed to the control grids of the modulators.

Positive voltage pulses of 6.5-7 kv. are fed from the output winding of T3 to the plates of the u.s.w. oscillator tubes.

The oscillator operates in a push-pull circuit with a common plate and uses plate modulation. Segments of bifilar lines shorted at the end are used in the cathode and grid circuits of the tubes. The interelectrode capacitances and the bifilar lines form a closed oscillator system.

Maximum delivery of power to the antenna is achieved by changing the length of the cathode line. A large increase of the cathode bifilar line leads to overloading the operation of the oscillator, and a large decrease leads to cut-off of the oscillation.

The amount of inductive reactance is changed by rebuilding the grid line, and in so doing the circuit frequency is changed and, therefore, the oscillation frequency. The oscillator tuning knob is brought out to the front panel of the unit. The ultrashort-wave oscillator functions during the pulse operation of the modulator (2 μsec.).

The energy of the high-frequency signal (f = 215-218 MHz) is taken from the cathode line and is transmitted from the oscillator to the antenna through the high-frequency output and the slip ring. The balanced output of the oscillator is matched to the unbalanced input of the antenna feeder system by a balun.

The power supply delivers 1800 v. to the transmitter for the submodulator plates, high voltage for the GMI-83 modulator plates, and 110 v. at 50 Hz for the filament transformers and the ventilator motor.

8.3. The Receiver

The radiotheodolite receiver is designed to amplify signals picked up by the antenna and convert them to a form convenient for the operation of the angle-coordinate indicator and the range indicator, as well as to record the signals with meteorological information.

The receiver is a superheterodyne and consists of a high-frequency section (h.f. amplifier, mixer, and oscillator), an intermediate frequency amplifier, a detector, a video pulse (v.p.) amplifier, and an audio frequency amplifier. The receiver functional diagram is shown in Fig. 8.7.

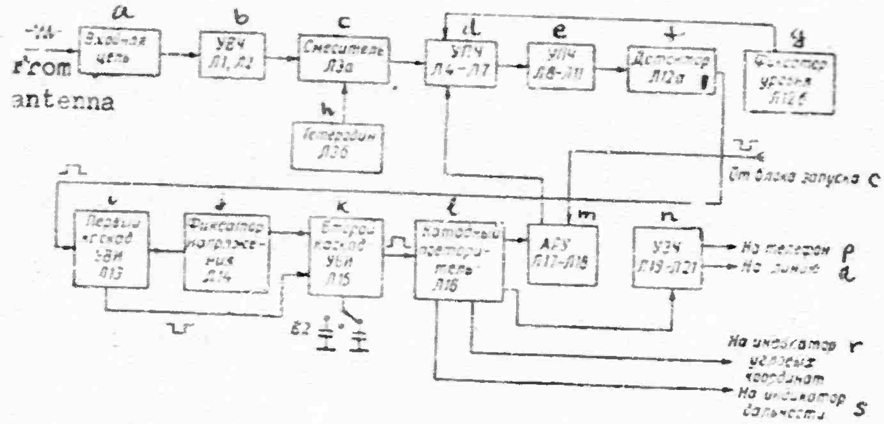

Fig. 8.7. Block diagram of the receiver

Key:
- a. Input circuit
- b. H.f. amp. (V1, V2)
- c. Mixer (V3a)
- d. I.f. amp. (V4-V7)
- e. I.f. amp. (V8-V11)
- f. Detector (V12a)
- g. Clamper (V12b)
- h. Local oscillator (V3b)
- i. First stage of v.p. amp. (V13)
- j. Voltage level clamper (V14)
- k. Second stage of v.p. amp. (V15)
- l. Cathode follower (V16)
- m. A.g.c. (V17-V18)
- n. A.f. amp. (V19-V21)
- o. From trigger unit
- p. To headphones
- q. To line
- r. To angle-coordinate indicator
- s. To range indicator

The local oscillator and mixer are assembled in a twin triode. The local oscillator (V3b) is a low-power self-excited oscillator with capacity coupling (the circuit is between the plate and the grid of the right half of the tube).

The 186-MHz signal generated by the local oscillator is fed to the mixer (V3a), as is the 216-MHz signal from the h.f. amplifier. Mixing of two signals at different frequencies (216 and 186 MHz) results in a more complex signal, which is also of high frequency; the amplitude of this signal, however, varies with a frequency equal to the difference of the two signal frequencies, 30 MHz. This frequency is called the beat frequency and is used as the intermediate frequency (i.f.). This frequency provides stable operation for the i.f. amplifier and sufficient receiver selectivity, and the dependence of the amplification and pass band of the i.f. amplifier on tube parameters is reduced.

The 30-MHz signal goes from the mixer to the i.f. amplifier, which provides the basic amplification of the signal and formation of the receiver pass band. The i.f. amplifier gain is on the order of $(100\text{-}150) \cdot 10^3$, and the pass band is 2.5-4.0 MHz.

The i.f. amplifier is built as a resonance amplifier with a single network in the control-grid circuit. The i.f. amplifier consists of eight identical stages. All oscillator circuits in the stages, which consist of inductance coils and the interelectrode capacitances of the tubes, are tuned to 30 MHz. Automatic gain control (a.g.c.) is effected in the first four i.f. amplifier stages (by feeding negative bias to the control grids from the a.g.c. circuit). To eliminate the possibility of a positive voltage of more than 1 v. appearing at the control grids of the controlled i.f. amplifier tubes, a clamper (V12b) is included in the circuit of these tubes.

From the i.f. amplifier output stage the signal voltage goes to the detector, which uses a 6Kh2P diode (V12a). The detected signals are isolated at the cathode load. These signals are positive voltage pulses having the shape of the high-frequency signal envelope.

At the detector output there is an additional filter at the intermediate frequency, through which the signal passes to the video-pulse amplifier. This amplifier is designed to increase the video pulses to a level sufficient for stable operation of the angle-coordinate and range indicators.

The video amplifier consists of four stages: two stages of v.p. amplification (V13 and V15), a voltage level clamper (V14), and a cathode follower (V16). The first v.p. amplifier stage is assembled as a resistance-coupled amplifier with negative current feedback. The amplification factor of the first stage is 10.

From the load of the first stage the amplified pulses of negative polarity go to the grid of the second pulse amplifier stage (V15), whose amplification factor is 8. The second stage of the video amplifier also includes regulation of the width of the pass band (selectivity), which is done by shunting the plate load of the first v.p. amplifier stage.

Condensers of different capacitances are used in conjunction with switch B2 in the grid circuit of the second stage to decrease the pass band (to reduce interference). At the amplifier output the signal acquires a quasi-triangular shape, i.e., its duration becomes minimum. The signal-to-noise ratio in this case increases, and the receiver's sensitivity is improved. When no interference is present, the signals are received using the wide pass band (the condensers are switched out).

In the video amplifier circuit V14 functions as a clamper on the grids of the tubes in the amplification stages. The clamper is assembled in a twin diode: the cathode of the left diode is connected to the control grid of the tube in the first stage, and the plate of the

right diode is connected to the control grid of the second amplifier stage. This use of a diode provides for rapid discharge of the coupling capacitors in the grid circuits and a constancy of the voltage on them regardless of the duration and repetition frequency of the pulses at the amplifier output.

The final v.p. amplifier stage of the receiver is a cathode follower (twin triode V16). In its cathode circuits there are four resistors for lifting and feeding the pulses to the a.g.c. circuit, the a.f. amplifier, and the angle-coordinate and range indicators.

Some of the output voltage from the cathode follower is fed to the a.g.c. circuit, which is designed to keep the level of the output signal constant when the amplitude of the radiosonde signal varies (due to fading) and to prevent receiver overload from strong signals. The a.g.c. circuit is assembled in two tubes: at V17 are the phase inverter and the detector, and at V18 is the cathode follower. When the transmitter is in operation, the a.g.c. circuit is cut off by a negative pulse from the trigger unit of the attachment. This is called the suppressor pulse and travels along the coaxial cable through the h.f. connector to the grid of V17 of the first a.g.c. stage.

The other part of the output voltage from the cathode follower of the video amplifier goes to the a.f. amplifier circuit.

The a.f. amplifier isolates and amplifies the main constituent low-repetition-frequency pulses (the meteorological information) and suppresses the main constituent high-repetition-frequency pulses (the pauses between the signals carrying the meteorological information).

The a.f. amplifier consists of three stages: a voltage amplifier (V19), a power amplifier (V20), and a cathode follower (V21). The power amplifier provides for transmitting a.f. voltage to the line (to the point where the radiosonde signals are received). The cathode follower is the final stage of the a.f. amplifier; the a.f. signals go from its output to the headphones.

The a.f. amplifier circuit includes a filter to suppress the powerful inquiry pulses of the rangefinder transmitter in the audio channel, which recur at a frequency of 1070 Hz.

A PR-16 automatic radiosonde-signal recorder may be connected to the output of the radiotheodolite receiver.

8.4. The Angle-Coordinate Indicator

The angle-coordinate indicator operates in two modes, "Operate" and "Check"; an amplitude signal reference mark is used.

In the "Operate" mode the signals from the radiosonde transmitter being tracked are visible on the screen of the indicator's cathode ray tube in the form of two pairs of pulses, which permits simultaneous

tracking of the radiosonde with respect to the angle of elevation and the azimuth. One pair of pulses corresponds to the angle of elevation, and the other pair corresponds to the azimuth (cf. Fig. 8.1).

Voltage from the control voltage generator (CVG) goes to the indicator circuit, where the voltage is shaped and the beam is cut off. In accordance with the four positions of the radiation pattern in space (left, upper, right, lower) the electron beam occupies in turn the following positions on the c.r.t. screen: the extreme left in the left pair of pulses, the extreme left in the right pair of pulses, the extreme right in the left pair of pulses, and the extreme right in the right pair of pulses. When the beam is switching from one position to another it is cut off by negative voltage applied to the c.r.t. modulator. In the "Operate" mode two channels operate in the angle coordinate indicator (Fig. 8.8), one controlling the sweep and one controlling the cut off of the electron beam.

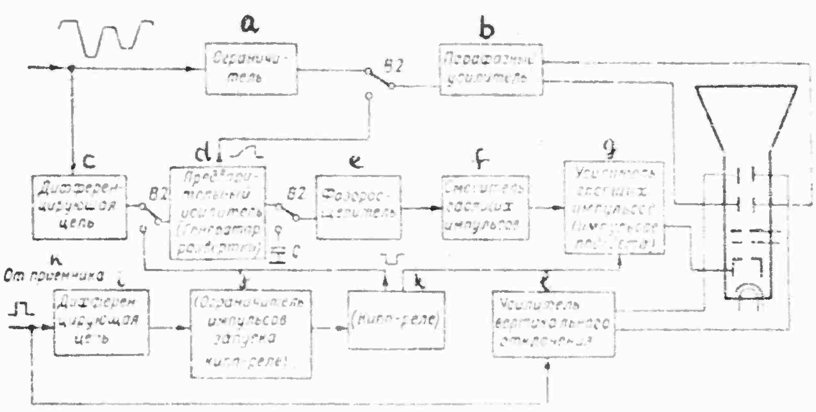

Fig. 8.8. Functional diagram of the angle-coordinate indicator

Stages operating in the "Check" mode are indicated in parentheses; switch B2 is shown in the "Operate" position.

Key:
a. Limiter
b. Paraphase amp.
c. Differentiating circuit
d. Preamp. (sweep generator)
e. Phase splitter
f. Cut-off pulse mixer
g. Cut-off (dimmer) pulse amp.
h. From receiver
i. Differentiating circuit
j. (Kipp relay trigger-pulse limiter)
k. (Kipp relay)
l. Vertical deflection amp.

The sweep channel consists of a diode limiter and a horizontal deflection paraphase amplifier. The limiter is constructed as a parallel diode amplitude gate with the CVG voltage applied to the input. Regulating the limiting threshhold at the top and bottom, they effect the change in the distance between the pulses in each pair. From the output of the limiter the sweep voltage goes to the two-stage horizontal deflection paraphase amplifier. This amplifier improves the electron beam focusing and increases the sensitivity of the indicator. From the outputs of the first and second stages of the horizontal deflection paraphase amplifier sweep voltages go in counterphase to the c.r.t. horizontal deflection plates.

Negative pulses are formed from the sweep voltage in the cut-off channel for total cut-off of the electron beam when it is switching from one position to another.

The cut-off channel consists of a cut-off pulse preamplifier (V3a), a phase splitter (V4a), a cut-off pulse mixer (V5), and a cut-off amplifier (pulse dimmer), V3b.

As noted above, voltage from the CVG goes to the diode limiter and simultaneously to the differentiating circuit. Bipolar pulses appear at the output of this circuit; their duration is equal to the duration of the drops in the control voltage. These pulses go to the cut-off pulse preamplifier and then to the phase splitter, which is a stage with plate and cathode loads. The bipolar pulses are fed from the plate and cathode of the phase splitter to the mixer.

The cut-off pulse mixer is a twin diode with a common cathode load, and it operates as follows. Suppose that a positive pulse comes from the phase splitter to the plate of the first diode and simulteneously a negative pulse comes to the plate of the second. In this case the second diode cuts off, and a positive pulse appears at the cathode load of the mixer. In the next voltage cycle a negative pulse appears at the plate of the first diode and a positive pulse at the plate of the second. The first diode cuts off and the second unblocks -- a positive pulse again appears at the cathode load. Thus only positive pulses will be isolated at the cathode load of the mixer; these then go to the cut-off pulse amplifier, where their amplitude is raised (to 100 v.) and their phase shifted by 180°. From the amplifier output the pulses go to the c.r.t. modulator and blank it for the time during which the electron beam switches from one position to another.

A positive pulse goes from the cathode follower of the video-pulse amplifier to the vertical deflection paraphase amplifier. A negative pulse is lifted from the first amplifier stage and applied to one of the vertical deflection plates; a positive pulse goes from the output of the second amplifier stage to the second vertical deflection plate. The amplification factor of each stage is 5, which provides pulses on the screen of the indicator with an amplitude up to 45 mm.

Signal amplitude on the indicator screen is controlled manually by a potentiometer connected at the input of the vertical deflection amplifier.

In the "Check" mode the indicator provides for checking the pulse shape from the transmitter being tracked. For this the mode switch B2 is set to the "Check" position. This switch cuts the diode limiter, phase splitter, and mixer out of the circuit.

In the "Check" mode the cut-off pulse preamplifier functions as a sawtooth-voltage generator, and the cut-off pulse amplifier functions as a sweep dimmer pulse amplifier. In addition, the Kipp relay, the Kipp relay trigger-pulse limiter, and the horizontal and vertical deflection amplifiers operate in the "Check" mode.

Video pulses from the receiver go to the differentiating circuit (cf. Fig. 8.8). Positive pulses trigger the Kipp relay, but negative pulses are limited by the diode, hence the operation of the Kipp relay is not disrupted by the trailing edge of the video pulse.[1]

Negative pulses from the Kipp relay go to the sweep generator. An 8-v. sawtooth-voltage pulse with a duration of 80-120 μsec. goes to the horizontal deflection paraphase amplifier. Sawtooth pulses of the opposite polarity are lifted from the amplifier outputs and fed to the c.r.t. horizontal deflection plates, producing the sweep. The negative pulse from the Kipp relay is also used to obtain the dimmer pulse for the retrace. A negative square-wave pulse goes from the Kipp relay to the dimmer pulse amplifier; here the pulse is amplified, shifted in phase by 180°, and then is fed to the c.r.t. modulator. The duration of the positive pulse is equal to the duration of the working scanning motion, hence only the retrace is dimmed. In the "Check" mode the vertical deflection amplifier operates just as in the "Operate" mode.

A type 8LO29 single-beam c.r.t. with a screen diameter of 80 mm. is used in the indicator. This diameter allows both the elevation-angle and azimuth bearings to be indicated simultaneously on the screen.

8.5. The Indicator Unit

The indicator unit for determining the slant range of the radiosonde or radiopilot consists of a trigger unit and a tube unit (the range indicator). The functional circuit of the indicator unit is given in Fig. 8.9.

The <u>trigger unit</u> forms synchronization pulses and reference voltages for controlling the operation of the transmitter, receiver, angle

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[1] Operation of the Kipp relay is described in Chapter 3.

coordinate indicator and tube unit.

The trigger unit consists of three channels: 1) pulse shaping with a repetition frequency of 1070 pulses/sec.; 2) phase shifter; 3) calibrator. The trigger unit also includes stages for forming the suppressor pulses that block the receiver and indicators during the powerful transmitter pulse.

A 75-kHz crystal oscillator provides the initial sinusoidal voltage for the three channels. The crystal is located between the control grid and the plate of the tube, and the plate circuit contains a resonant circuit tuned to the crystal frequency. The voltage goes from this circuit to the trigger unit channels. The 75-kHz signal from the oscillator is applied to the input of the first 2:1 frequency divider of the pulse-forming channel. A blocking oscillator is used as the divider. The divider circuit includes provision for establishing the required division ratio by changing the repetition frequency of the blocking oscillator pulses. Pulses at a frequency of 37.5 kHz are taken from the output of the divider for synchronizing the operation of the second divider.

The 7.5-kHz pulses from the divider synchronize the operation of the third divider and also go to the coarse-sweep selector (the B-16 tube unit).

The third divider is also a blocking oscillator; the division ratio of this stage is 7:1. Thus pulses with a repetition frequency of 1070 pulses/sec. appear at the output of this divider. These pulses are used for forming the pulses of the transmitter unit, the suppressor pulses, and the coarse sweep voltage.

From the third divider the pulses go to the stage that forms the transmitter trigger pulses; this stage consists of a Kipp delay relay, a selector stage, and a transmitter trigger pulse generator. The Kipp relay delays the transmitter trigger pulses relative to the pulses of the third divider which trigger the relay; this delay is 26.5 μsec. This is necessary in order to match the narrow gate (the electronic hairline) with the range zero. The Kipp relay develops a positive square-wave pulse which goes to the selector. Pulses from the first stage at a repetition frequency of 37.5 kHz also go to the selector. The selector stage synchronizes the transmitter trigger pulse and the pulse from the first divider. The circuit of the selector stage goes into operation when the Kipp relay pulse coincides with the pulse from the first divider. From the output of the selector the pulse goes to the transmitter trigger-pulse generator. From the output of this generator the pulses are fed through coaxial cable to the transmitter and trigger it.

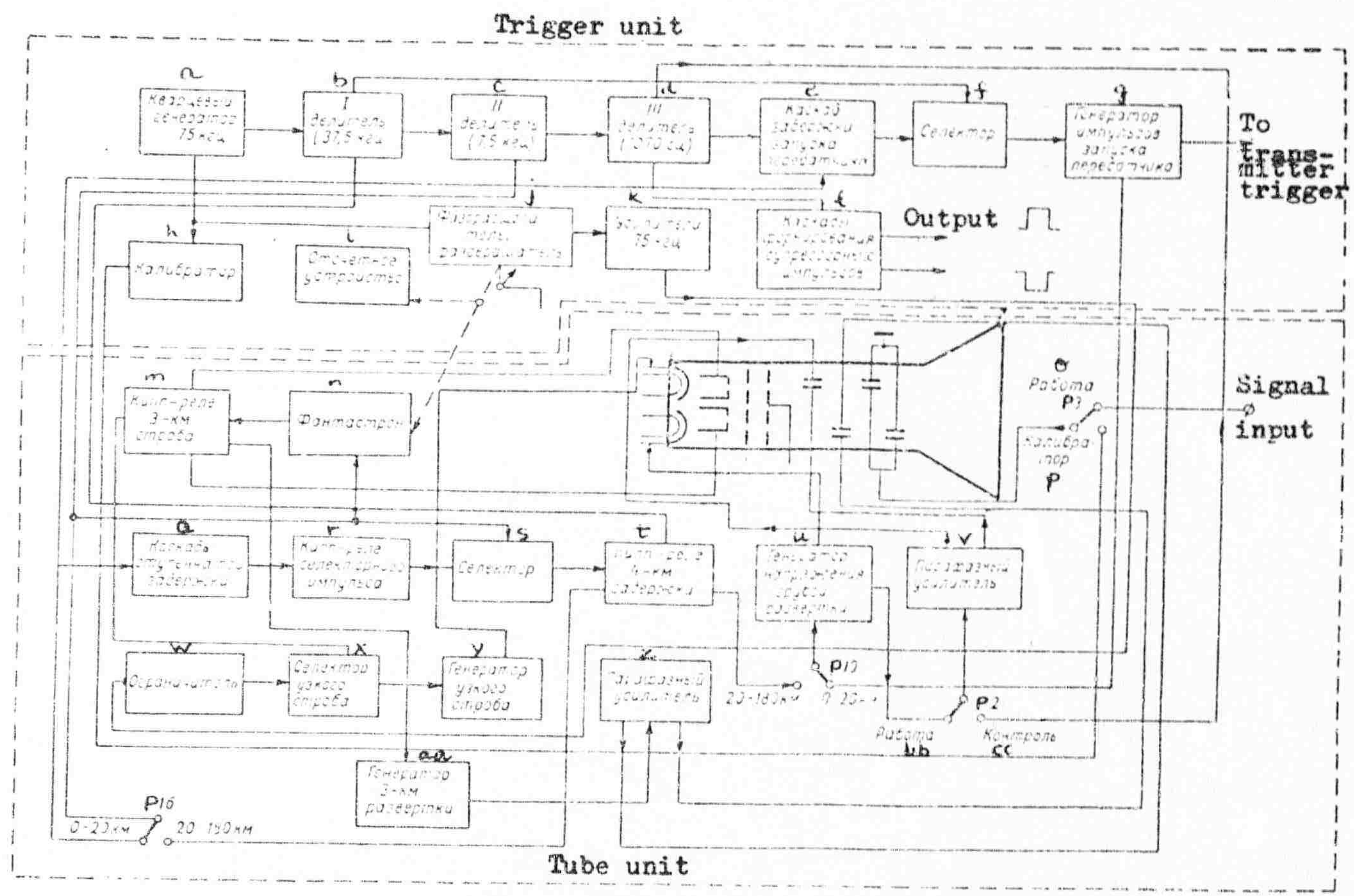

Fig. 8.9. Functional circuit of the indicator unit
[Key on following page]

Key: a. Crystal oscillator (75 kHz)
b. First divider (37.5 kHz)
c. Second divider (7.5 kHz)
d. Third divider (1070 Hz)
e. Transmitter pulse delay stage
f. Selector
g. Transmitter trigger-pulse generator
h. Calibrator
i. Reading device
j. Phase splitter, phase shifter
k. Amplifiers (75 kHz)
l. Suppressor-pulse forming stages
m. Kipp relay of the 3-km. gate
n. Phantastron
o. Operate
p. Calibrator
q. Stepped-delay stages
r. Kipp relay of the selector pulse
s. Selector
t. Kipp relay of the 4-km. delay
u. Coarse-sweep voltage generator
v. Paraphase amplifier
w. Limiter
x. Narrow-gate selector
y. Narrow-gate generator
z. Paraphase amplifier
aa. 3-km. sweep generator
bb. Operate
cc. Check

To determine the slant range of the transmitter/transponder (of the radiosonde) the electronic hairline must be matched with the image of the answering pulse and then readings taken from the special range scales. The electronic hairline is formed from the 75-kHz voltage applied to the phase shifter channel, which consists of two stages (a phase splitter and a phase shifter) and two 75-kHz sinusoidal-voltage amplifiers. The phase shifter is connected to the range mechanism.

The voltage from the output of the phase shifter is amplified and fed to the tube unit (the range indicator) into the channel that forms the narrow gate (the electronic hairline in the form of a dark mark).

As the handwheel is rotated (the axis of the phase shifter), a fine sweep moves across the screen of the cathode ray tube, the dark mark of the narrow gate remaining fixed.

Calibration markers are used to check the operation of the phase shifter and the reading device. Voltage from the crystal oscillator is used to obtain the calibration marks. This voltage is fed into the calibrator channel to the frequency multiplier (4 x 1). The 300-kHz voltage

goes to the tuned amplifier and then through the cathode follower to the c.r.t. vertical deflection plates. Since the distance between the markers is exactly 500 m. (the frequency is 300 kHz), the precision of the reading unit can be checked by matching the marker with the electronic hairline. The calibrator channel operates only when the range indicator is tuned (in the "Check" mode).

The <u>tube unit</u> consists of a channel forming the coarse and fine sweep voltage, a channel forming the narrow gate voltage (the electronic hairline), and a channel that amplifies the signal. A two-beam 13LO48 c.r.t. (screen diameter 130 mm.) is used for an indicator.

Stepped delay of the coarse sweep in segments of 20 km. is used in the circuit. In the 0-20 and 140-160-km. segments the pulses from the third divider directly trigger the coarse-sweep voltage generator, since, with a repetition frequency of 1070 Hz, at a distance of 140 km. the second sounding pulse is emitted, and the 140-160-km. segment of the scale corresponds to the 0-20-km. segment.

In the 20-40, 40-60, ..., 180-200-km. range segments the pulse from the third divider goes to the stage controlling the stepped delay (relative to the beginning of the transmitter trigger pulses) of the sweep (up to 180 km. in 20-km. segments).

The output pulses from the stepped-delay stage are used to trigger the selector-pulse Kipp relay; pulses from the Kipp relay go to the selector, which also receives pulses from the second divider of the trigger unit at a repetition frequency of 7.5 kHz. Whenever a Kipp relay pulse coincides with one of the pulses from the second divider, the selector stage will give out a positive pulse triggering the coarse-sweep voltage generator. This gives a delay in the coarse sweep relative to the pulses from the third divider in 20-km. segments.

The positive pulse goes from the coarse-sweep voltage generator to the paraphase amplifier, from which negative and positive pulses are fed to the horizontal deflection plates of the first beam of the c.r.t.

The pulses from the second divider of the trigger unit also trigger the phantastron. The length of the phantastron output pulse (from 4 to 24 km.) depends on the setting of the range potentiometer. Since the Kipp relay of the 3-km. gate is triggered by the phantastron pulse, the position of the 3-km. gate is maintained on the sweep at all distance segments.

The negative pulse from the Kipp relay of the 3-km. gate triggers the fine (3-km.) sweep voltage generator, from which voltage is fed to the paraphase amplifier and then to the horizontal deflection plates of the second beam of the c.r.t.

The output voltage of the phase shifter channel (the trigger unit) is fed to the tube unit to form the electronic hairline (dark mark). The first stage of this channel contains a limiter. The upper and lower limits of the (75-kHz) sinusoidal voltage are controlled in this stage, the result of which is that the differentiating circuit receives a square-wave voltage, which is then fed to the selector forming the narrow gate.

The selector stage passes only positive pulses after differentiation. In addition, the selector tube is normally cut off and unblocks only when a positive pulse from the Kipp relay of the 3-km. gate coincides with a positive pulse from the differentiating circuit.

The negative pulse of the selector stage is amplified, shifted to the opposite phase, and triggers the generator forming the narrow gate. The generator is assembled as a blocking oscillator from whose output a positive voltage pulse of 0.2-0.3 μsec. duration is lifted and fed to the cathode of the c.r.t. (the fine sweep).

From the cathode load of the coarse-sweep voltage generator the negative square-wave pulse goes to the second cathode for dimming the coarse sweep. The positive pulse from the Kipp relay of the 3-km. gate goes to the tube modulator to form the bright mark (of the 3-km. gate) at the coarse sweep; it also goes to the fine-sweep modulator system for dimming the retrace.

The transmitter/transponder signal goes through the receiver section of the radiotheodolite to the signal amplifier in the tube unit and then to the vertical deflection plates of the first and second beams.

8.6. The Power Supply System

The radiotheodolite and rangefinder attachment are connected to a single-phase, 127-220-volt alternating-current (50 Hz) electrical network by means of a pole panel through which the power is fed to independent power panels of the radiotheodolite and the attachment (Fig. 8.10).

From the power panels a voltage of 127-220 v. goes to the distribution and protection unit (DPU) and to the B-18 power unit of the attachment. In these two units there are variable-ratio transformers, from whose output the 110 and 220 v.a.c. is taken. The 110 v. line is fed to the transmitter rectifier, selsyns, blowers, outlets, and also to the B-18 rectifier unit of the rangefinder attachment and the B-5 supply unit of the radiotheodolite.

The 220 v.a.c. is used only for triggering the electric motor of the antenna commutator.

From the supply unit (B-5) a rectified voltage of 120 and 280 v. is delivered to the receiver plate and cathode circuits, and 280 and

1500 volts is delivered to the angle-coordinate indicator. A 6.3-v.a.c. line feeds the filament circuits of the receiver and the indicator.

The B-18 supply unit (a -105 v. rectifier) fulfils the same functions as the DPU, i.e., it provides for turning on the rangefinder attachment, regulating the amplitude of the supply voltage using the variable-ratio transformer, and protecting and shutting off all units. From the B-18 supply unit a rectified voltage of -105 v. is fed to the trigger unit, the tube unit, and to the 250 v. rectifier. To stabilize the -105 v., 250 volts is fed to this unit from the B-15 supply unit. A 250-v. line also supplies the trigger unit, range indicator (tube unit) and the B-21 high-voltage rectifier, which provides -1800 v. to the range indicator.

Rectified voltage of 1800 and 7700 volts is fed from the B-19 unit to the transmitter (B-20).

The filament circuits of the tubes in the trigger units and the high-voltage rectifier are supplied with 6.3 v. from the B-18 supply unit, and filaments of the tube unit are supplied from the B-15 supply unit. The B-18, B-15, and B-19 supply units and the transmitter include filament transformers that supply 6.3 v. to the filament circuits of these units.

8.7. The A-35-1P Transmitter/Transponder

The transmitter/transponder (Fig. 8.11) works in four modes: super-high frequency (216 MHz), the frequency of the impact-excitation oscillator (400 kHz), and as a squitter with high (above 2900 Hz) and low (300-2300 Hz) frequencies.

Let us examine the operation of the superhigh-frequency (s.h.f.) section of the transmitter. To obtain the s.h.f. signal (216 MHz) an oscillator circuit is used which employs parallel feed with capacitive feedback which occurs because of the interelectrode capacitances of the tube (2S3A). The oscillator circuit consists of an open coil of wire functioning as a long-line segment (band loop), the interelectrode capacitance of the tube, and the capacitance and inductance of the assembly. At the aerological station before it is sent up, the transmitter's fine tuning is adjusted by shifting the slider on the plate end of the band loop. The circuit is inductively coupled to the antenna, which is a half-wave dipole 600 mm. long.

When the power supplies are turned on the plate current begins to flow (from +A through coil L1, choke Ch1, and the tube) and the h.f. signal appears in the circuit.

The high-frequency chokes Ch1 and Ch2 prevent the high-frequency waves from leaving the circuit and at the same time allow normal passage of direct current: plate current through Ch1 and grid current through Ch 2.

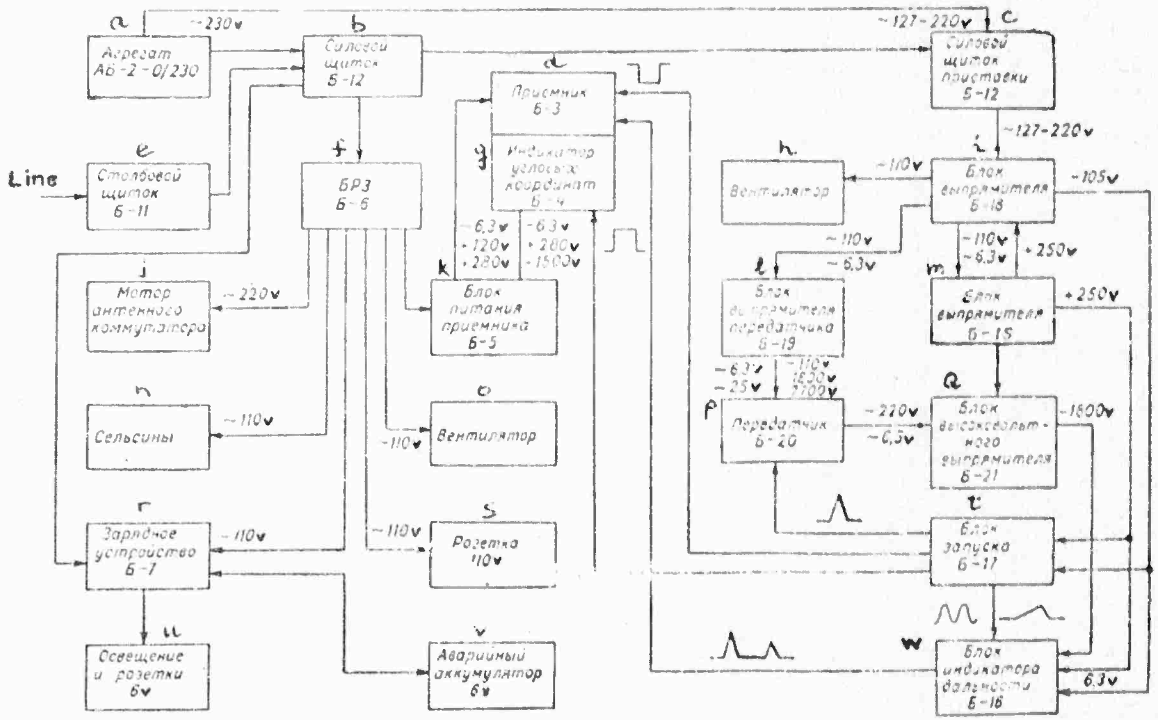

Fig. 8.10. The Malachite power supply system
[Key on following page]

Key: a. Assembly AB-20/230
b. Power panel B-12
c. Attachment power panel B-12
d. Receiver
e. Pole panel B-11
f. DPU B-6
g Angle-coordinate indicator B-4
h. Blower
i. Rectifier B-18
j. Antenna commutator motor
k. Receiver supply unit B-5
l. Transmitter rectifier unit B-19
m. Rectifier unit B-15
n. Selsyns
o. Blower
p. Transmitter B-20
q. High-voltage rectifier unit B-21
r. Charger B-7
s. Outlet 110 v.
t. Trigger unit B-17
u. Lighting and outlets 6 v.
v. Emergency battery 6 v.
w. Range indicator unit B-16

During oscillation the magnitudes and signs of the charges on the grid and cathode of the tube vary because of the interelectrode capacitances, which leads to a variation in the plate current, i.e., an alternating current appears here along with the direct current. The alternating component of the plate current goes through separating capacitor C2 and supports the s.h.f. oscillation in the oscillator circuit. During the positive half-cycles a current appears at the grid which flows through resistor R2, choke Ch2, and part of the band loop to the grid of the tube. A voltage drop appears at R2, placing negative bias on the grid. Condenser C5 begins to charge. after a significant negative charge has accumulated on the plate of condenser C5 connected with the grid of the tube, the tube cuts off and the high-frequency oscillations stop. After these oscillations stop the charge on the condenser also stops and it discharges, depending on which "manipulative" leads (1, 2, 3) are switched in through resistors R3 and R4. It takes longer for the condenser to discharge than to charge; this time can be calculated from the values of the capacitances and resistances included in the grid circuit using the well-known formula $\tau = RC$.

After condenser C5 discharges, the oscillations appear again and the process is repeated.

The commutator system of the A-22 radiosonde (the code drum) periodically closes the manipulative pair, resulting in squitter, whose

frequency is determined by the values of the resistors and capacitors in the grid circuit of the transmitter. To receive the radiosonde signals by ear it is necessary for the transmitter to have a squitter with a frequency of 300-600 pauses/sec.

To obtain this squitter lead 2 is connected to the radiosonde, and the commutator closes this lead with the filament lead. Condenser C5 is thus connected in parallel with R2.

To receive signals using the automatic recorder (PR-16) the transmitter must work in a squitter mode with a constant frequency; for this manipulative leads 2 and 3 are interconnected and connected to the radiosonde. Manipulative lead 1 is also connected to the radiosonde. When these leads are connected by the radiosonde commutator half of the battery potential at anode +A is fed to the grid of the transmitter tube (from the divider formed by resistors R1 and R4), and resistor R3 is switched in in parallel with resistor R2. This results in a sharp increase of grid current and squitter with a frequency of more than 290,000 pulses/sec.

The A-35-1P operating conditions when transmitting meteorological information are as follows.

1) With squitter of 300-2300 pulses/sec. the duration of the high-frequency pulse is 30-60 µsec. and that of the pause is 2000 µsec.;

2) With squitter of more than 2900 pulses/sec. the duration of the high-frequency pulse is 0.7-0.9 µsec. and that of the pause is 4 µsec.

For determining slant range the transmitter must be able to answer the inquiry pulses of the Malachite radiotheodolite rangefinder attachment, which sends inquiry pulses with a frequency of 1070 pulses/sec. In the answering mode the manipulative leads are not connected (the radiosonde commutator does not connect them). For receiving the answer the A-35-1P transmitter must work as a superregenerative receiver, i.e., it must be able to receive the inquiry signals sent by the Malachite rangefinder attachment.

To enable the transmitter to work as a superregenerative receiver there must be an auxiliary sinusoidal-wave oscillator, which is called an impact-excitation oscillator.

The impact-excitation oscillator is assembled in a series-fed circuit with autoinductive coupling, which is effected by feedback coil L2.

The oscillator circuit (L1, C1) is tuned to 400 kHz. When the supply sources are switched into the oscillator circuit, as in the usual closed oscillator circuit, sinusoidal oscillations appear. A varying potential difference is induced in feedback coil L2; this difference is applied through C3 to the cathode of the tube and

through C4, Ch2, and part of the band loop to the grid of the tube. Under the influence of the potential difference applied to the grid and the cathode, the plate current shows an alternating component of 400 kHz which, passing through Ch1, supports the oscillations in the L1-C1 circuit. Since Ch1 and Ch2 have a large reactive resistance at 216 MHz and a small reactive resistance at 400 kHz, they do not block the alternating component of the plate current.

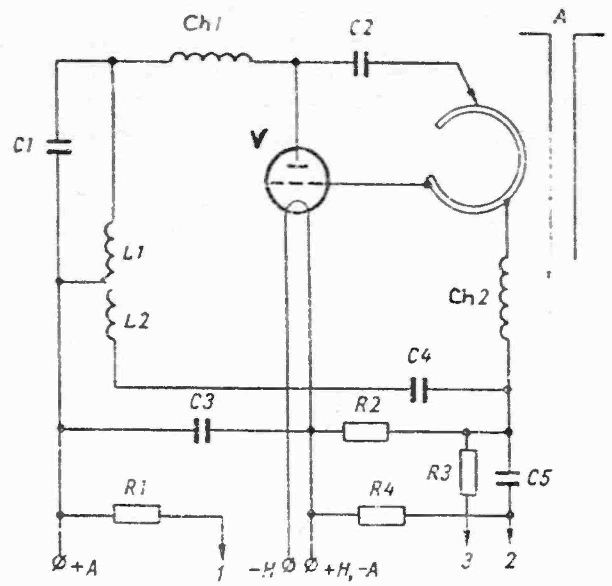

Fig. 8.11. Circuit of the A-35-1P transmitter/transponder

Let us consider the joint operation of the impact-excitation oscillator and the s.h.f. (216 MHz) oscillator. The superregenerator operates in the transmitter/transponder in a linear mode in which, when the inquiry pulse is received, not only is the time of the emission of the routine signal by the impact-excitation oscillator changed, but also the amplitude and power of the emission of the high-frequency pulses are increased by 10-20%.

In the positive half-cycles of the oscillations of the impact-excitation oscillator, oscillations whose duration is 0.7-0.9 µsec. appear at the grid of the tube in the s.h.f. circuit. Because of the large grid current, C4 charges at this time, and the negative potential on the grid of the tube sharply increases, cutting it off. The tube is cut off for approximately 14 µsec., and during this time C4 discharges through R2. For half of this time, approximately 7 µsec., the negative potential on the grid does not exceed 0.2 µv., and the transmitter becomes a receiver able to receive the inquiry pulse from the radiotheodolite rangefinder attachment. Thus, every 14-15 µsec. the

transmitter emits a routine pulse (a packet of high-frequency oscillations). Consequently, the frequency of pulse emissions is on the order of 40-60 thousand pulses/sec.

The rangefinder attachment of the Malachite radiotheodolite sends 1070 inquiry pulses per second (their duration is 2 μsec.). If an inquiry pulse is received during the time when the negative potential on the grid does not exceed 0.2 μv., the oscillations in the high-frequency circuit that result from it can unblock the tube, resulting in a special emission of the high-frequency pulse; this is the "answer." After this emission there is a pause which lasts longer than the pause between the routine pulses emitted by the transmitter, since condenser C_4 does not completely discharge during the answering pulse. An answer is not produced during the instant when the transmitter is on (emitting high-frequency oscillations), or when the tube is blocked by a high negative potential.

Thus, not every inquiry pulse from the rangefinder attachment of the Malachite radiotheodolite is answered; several hundred answers per second are received, however, which is quite sufficient for determining the slant range.

On a background of super noises (the routine high-frequency pulses from the transmitter/transponder) a pause appears on the screen of the rangefinder attachment indicator; before this pause a pulse is visible which is greater in amplitude than the others. This is the answering pulse. The hairline is matched to it and the range is read from the scale.

Test Questions

1. List the main tactical and technical specifications of the Malachite radiotheodolite.

2. What is the principle behind the operation of the Malachite radiotheodolite with rangefinder attachment?

3. List the main units in the station and their function.

4. What are the components of the antenna feeder system?

5. Draw a block diagram of the transmitter. What is the function of its units?

6. What are the stages in the radiotheodolite receiver? Where do the output pulses from the receiver unit go?

7. What is the difference in the operation of the angle-coordinate indicator in the "Operate" and "Check" modes?

8. What is the function of the trigger unit? What are the channels in this unit?

9. What are the channels in the tube unit (range indicator)?

Chapter 9

The "Meteorite" Meteorological Radar Station

The Meteorite radar station is designed to track radiosondes of the RKZ type in meteorological sounding of the upper layers of the atmosphere and also for tracking radiopilots (passive corner reflectors).

In working with a radiosonde, the station determines and records the angle coordinates, the slant range, the flight time, and the quantities of meteorological elements.

In working with a radiopilot, the station determines and records the running coordinates (azimuth, angle of elevation, slant range) and the flight time. Wind speed and direction can be determined from the flight time and the running coordinates.

BASIC TACTICAL AND TECHNICAL SPECIFICATIONS OF THE METEORITE STATION

1.	Working frequency	1770-1795 MHz (λ = 17 cm.)
2.	Transmitter pulse power	200 kw.
3.	Sounding pulse sending frequency	833 p/sec.
4.	Transmitter pulse duration	0.8 μsec.
5.	Receiver sensitivity	$5 \cdot 10^{-13}$ w.
6.	Radiation pattern width at half power ($0.5\ P_{max}$)	$6.5 \pm 1°$
7.	Range of automatic radiosonde tracking with recording of coordinates and meteorological data	150 km.
8.	Working limits along the azimuth: unlimited along the elevation angle: from -3° to +90°	
9.	Error in determining angle coordinates in autotracking mode: no more than 0.12°	
10.	Error in determining range in autotracking mode: of the radiosonde, no more than 40 m., of the radiopilot, no more than 25 m.	
11.	Frequency of the conic scanning of the radiation pattern	24 Hz
12.	Limits of sector scanning	20° x 20°
	Scanning time	20 sec.

13.	Precision of data recording:	
	from angle coordinates	0.6°
	from range	10 m.
	from frequency	1 Hz
14.	Recording rate:	
	meteorological data	5 sec.
	spherical coordinates and time	30 sec.
15.	Supply voltage	220 v., 400 Hz
16.	Power consumption	13.5 kw.

The Meteorite radar station can track the type RKZ-2 radiosonde or a corner reflector. In the latter case the meteorological data are not determined. The Meteorite-RKZ system employs the principle of using a single radio channel to transmit frequency-modulated signals of the meteorological elements and range signals (inquiry-answer).

The RKZ-2 radiosonde has three pickups: a pressure pickup, included in a baroswitch assembly which turns on in a specific sequence the temperature pickup (thermistor), the potentiometer connected with the humidity pickup, and the reference resistance (a resistance of high stability). Depending on the position of the pointer on the baroswitch scale the reference resistance, the reference resistance and the thermistor, or the reference resistance and the humidity potentiometer are switched in between the control grid of the first tube (the measuring oscillator) and its cathode. Since the resistance of the thermistor and the humidity potentiometer depends on the magnitudes of the appropriate meteorological elements, the resistance of the grid-cathode section of the measuring oscillator tube will vary depending on which resistance is switched in at a given moment and what the value of the temperature or humidity is. When only the reference resistance is connected to the grid of the tube, the radiosonde generates a so-called fundamental frequency.

The radio section of the radiosonde has three stages (Fig. 9.1): V1 (2P29P), the measuring oscillator, V2 (2P29P), the modulator, and V3 (6S21D), the s.h.f. oscillator. Depending on the value of the resistance in the grid-cathode section, the measuring oscillator develops a corresponding number of negative pulses that block the s.h.f. oscillator tube, pauses appearing at the output of the s.h.f. oscillator, and the meteorological information and the fundamental frequency are thus transmitted. The modulator serves as an auxiliary oscillator for turning the s.h.f. transmitter into a superregenerative receiver (similar to the Malachite-A-35-1P transmitter system). The s.h.f. oscillator develops a carrier frequency signal of 1782 MHz ($\lambda = 17$ cm.).

The measuring oscillator is assembled in a phantastron circuit. A characteristic of this circuit is the connection between the plate and the control grid of the pentode V1 (2P29P) through condenser C1 (the appropriate capacitance, C1 + C0 + ... is chosen at the factory

when the unit is aligned). Condenser C2 connects the screen and suppressor grids, which provides for self-excitation in the oscillator.

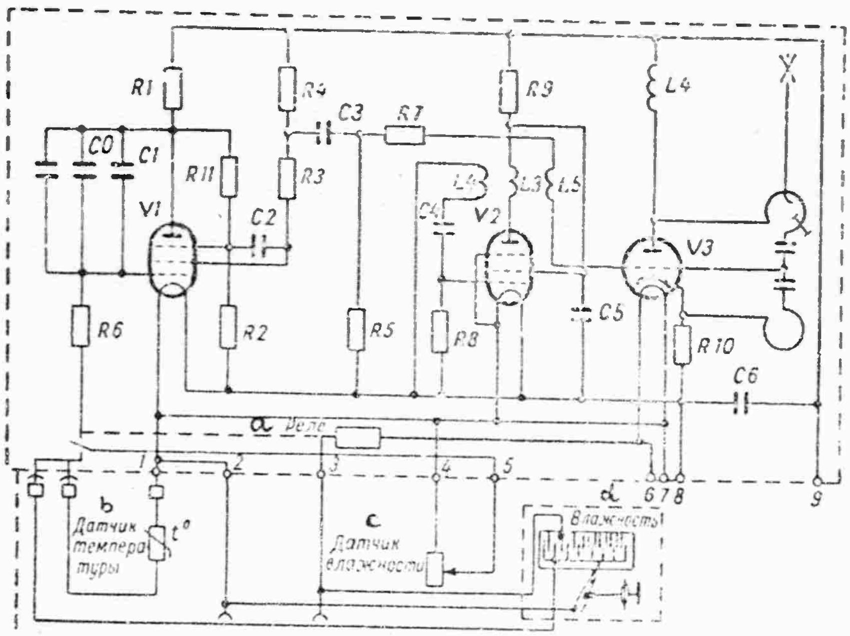

Fig. 9.1. Schematic of the RKZ-2 radio section

Key: a. Relay
b. Temperature pickup
c. Humidity pickup
d. Humidity

Let us now consider the operation of the circuit from the time when condenser C1 has been fully charged through resistors R1 and R6 (we shall consider the operation of the circuit during the time when the reference resistance R6 has been switched into the control grid-cathode circuit). Condenser C1 will discharge through the tube V1 and R6. A voltage drop appears at R6, placing negative bias on the control grid of the tube; consequently, the discharge current (the plate current of the tube) will be small and the discharge of C1 will be extended. As C1 is discharging, C2 is charging up to a voltage almost equal to the plate supply voltage.

A decrease of the voltage on C1 will result in a decrease of the negative voltage on the control grid, resulting in screen-grid current. Condenser C2 begins to discharge through the tube (screen grid-cathode) and R2. A difference potential appears ar R2, placing

negative bias on the suppressor gird, which prevents plate current, and thus C1 (which has almost discharged) begins to charge through R1 and R6. The charge current of C1 causes a voltage drop at R6, placing positive bias on the control grid; this in turn results in an increase in screen-grid current and the rapid discharge of C2. After C2 has discharged, the circuit returns to its original state and C1 begins to charge through V1 and R6, and the process repeats over and over. With a change in the value of the resistance in the control grid-cathode circuit the discharge time for C1 increases (the time constant becomes greater). The operation of the circuit does not change, but the number of pulses per second developed by the oscillator will be different. The measuring oscillator of the RKZ-2 radiosonde develops from 100 to 2300 p/sec.

The load of the measuring oscillator is R5, which is connected to it through C3. As can be seen from the schematic, C3 will charge and discharge at the same time as C2. As C3 discharges through the screen grid-cathode sections of the tube and R5, a voltage drop appears at this resistor, placing negative bias on the control grid through R7 and L5, and positive bias on the cathode of the s.h.f. oscillator. Because of this difference potential the s.h.f. oscillator cuts off for 50-300 µsec.

The s.h.f. oscillator is assembled at V3 (6S21D or 6S11D) which is set in a metal cylinder with plungers forming the two cavities of the circuit: the plate cavity and the grid cavity. The plate circuit contains the high-frequency signal output, which goes through coaxial line to the antenna. The transmitter antenna system is a half-wave dipole tuned to 1782 MHz which provides directed radiation towards the ground (the radiosonde antenna is aimed downward).

The modulator operates at V2 (2P29P) and is a sine-wave oscillator assembled in an oscillator circuit with series feed transformer coupling. The modulator provides the pulse mode for the operation of the s.h.f. oscillator (pulse power, 0.5w.) and at the same time turns the transmitter into a highly sensitive superregenerator. The purpose of the modulator is the same as that of the impact-excitation oscillator in the A-35-1P transmitter/transponder. The modulator oscillation circuit is coil L3, which has sufficient inductance and capacitance to create oscillations of 800 kHz. When the modulator is in operation a variable potential difference appears at coil L5 and is applied to the grid and through resistors R7 and R5 to the cathode of the s.h.f. oscillator tube. During the negative half-cycles the s.h.f. oscillator cuts off for 0.5-0.6 µsec., and the oscillator takes on the properties of a superregenerative receiver, i.e., it is able to receive the inquiry pulses sent by the Meteorite radar station. When an inquiry pulse reaches it the s.h.f. oscillator tube unblocks and a high-frequency pulse of increased amplitude is generated, followed by a 1 µsec. pause. This is the answering signal (pulse).

It can be seen from the above that the radio section of the RKZ-2 radiosonde operates at a frequency of 1782 MHz, which is modulated by a frequency of 800 kHz. The radiosonde emissions are periodically interrupted by negative pulses from the measuring oscillator whose duration is 50-300 μsec., which are designed for receiving the meteorological information. When inquiry pulses from the radar station reach the radiosonde, 1-μsec. pauses appear in its emission. The pauses containing meteorological data and the answering pauses are of different durations and are thus easily separated at the radar station and directed into the appropriate channels, meteorological data into the read-out system and answers into the range-measuring system.

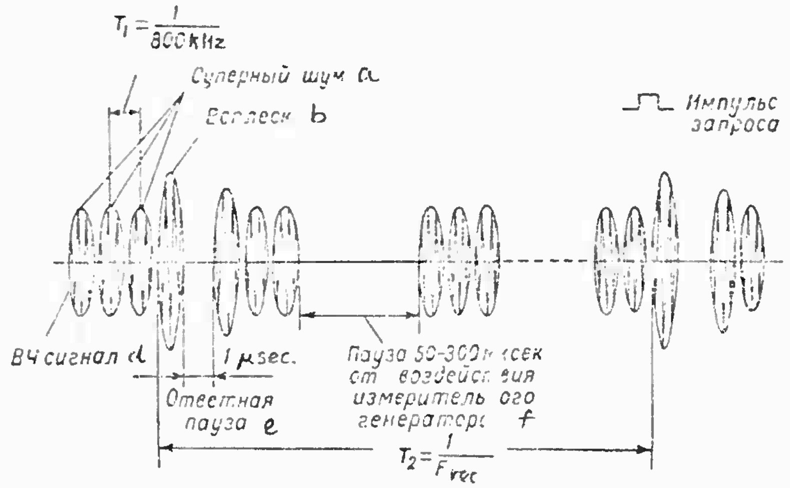

Fig. 9.2. Signal shape of the RKZ radiosonde

Key: a. Super noise
b. Burst
c. Inquiry pulse
d. H.f. signal
e. Answering pause
f. 50-300-μsec. pause due to operation of the measuring oscillator

The shape of the signal emitted by the radiosonde transmitter is shown Fig. 9.2.

Use of the transmitter/transponder allows running coordinates to be determined at significantly greater distances than when the corner reflector is used, since the power of the signal emitted by the radiosonde transmitter is much greater than the power of the signal reflected from the passive circuit.

In tracking the corner reflector the station operates as an ordinary pulse radar station.

The station incorporates the following systems: a transmitting system (MT-10), an antenna feeder system (MT-20), a receiver system (MT-30), a reading system (MT-40), a range measuring system (MT-50), a data registering and recording system (MT-60), an antenna control system (MT-70), and a power supply system (MT-80).[1]

The power supply system provides all systems of the station with voltages necessary for normal operation. The power supply system includes: a voltage control panel, a voltage control box, and three supply units. Many radio units in the station are fed by self-contained rectifiers stabilized by electronic voltage stabilizers.

The Meteorite station also includes a set of testing and measuring equipment intended for tuning and adjusting the units and systems: a test resonator (MT-92), a C1-5 pulse oscillograph, an AVO-5 volt-ohm-ammeter, etc. The test resonator is included in the station's antenna feeder system and is used to check the tuning of the receiver system, the frequency of the magnetron oscillator, the klystron heterodyne, etc.

9.1. The MT-10 Transmitting System

The transmitting system of the station is designed to develop powerful (200 kw.) short-duration (0.8 μsec.) pulses of high frequency (1770-1795 MHz). It consists of a transmitter (submodulator, modulator, and magnetron oscillator), a supply source, and control interlocking and signaling circuits. The transmitting system is installed in a spearate cabinet.

Transmitter. The basic circuit is shown in Fig. 9.3.

Submodulator. Sharp positive pulses at a frequency of 833 Hz come from the range system into the transmitter and trigger it. The submodulator transforms them into powerful positive pulses for controlling the operation of the modulator. The submodulator consists of a trigger-pulse amplifier, a blocking oscillator, and a power amplifier.

The trigger-pulse amplifier amplifies the incoming pulses to 120 v. and feeds them to the blocking oscillator. The trigger-pulse amplifier and blocking oscillator are assembled in a double beam tetrode, GI-30 (V1). An artificial (forming) extension line, FL-1, is included in the blocking oscillator grid circuit to shape the duration of the square-wave pulses.

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[1] The notation of the systems used in the technical description of the station is given in parentheses.

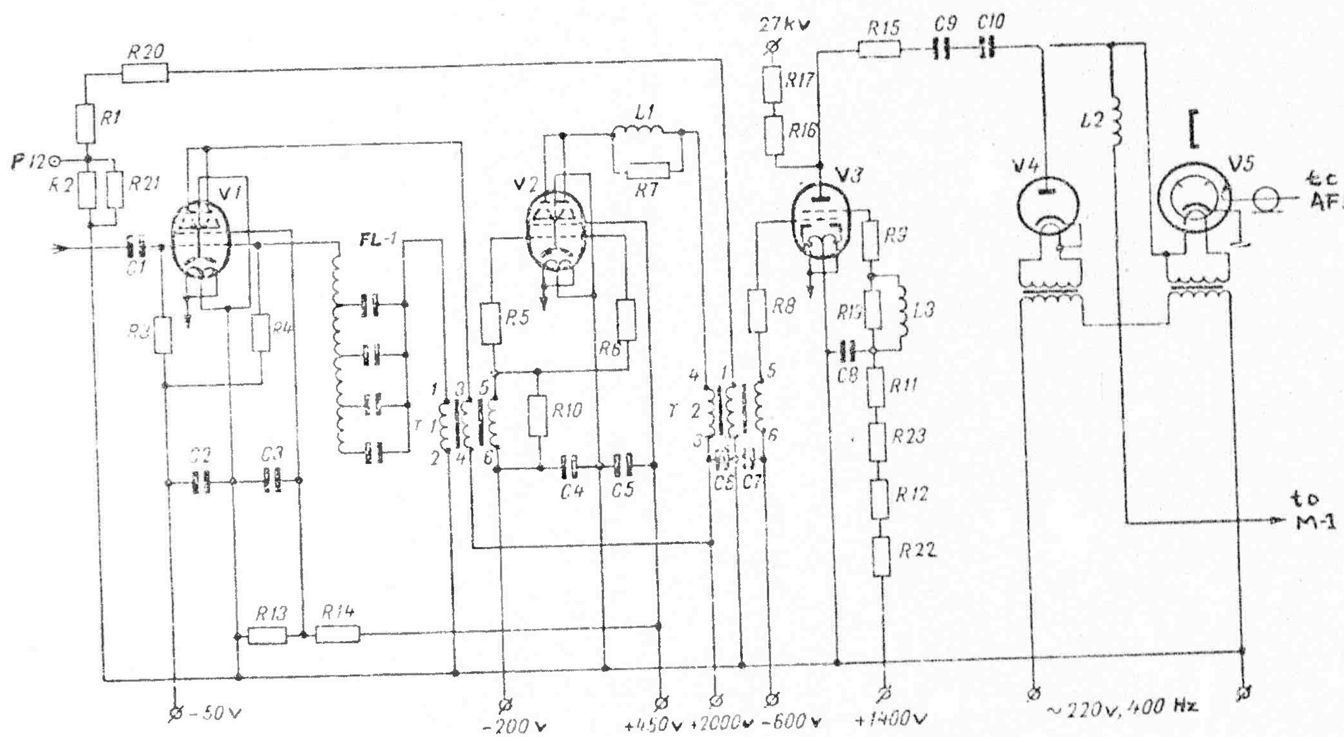

Fig. 9.3. Basic schematic of the transmitter

A blocking voltage of -50 v. is fed to the grids of both halves of V1 in the intervals between the trigger pulses. A 60-v. trigger pulse unblocks the left tetrode, resulting in an amplified pulse appearing at the ends 3-4 of the winding of transformer T1; through the coupling coil 1-2 this pulse operates on the control grid of the blocking oscillator (the right half of V1). The ends of the transformer coil 1-2 are connected so that a positive voltage appears on the grid of the blocking oscillator and the plate current of this tube begins to avalanche until it is saturated. As soon as the plate current stops increasing the FL-1 forming line begins to discharge. The potential at the blocking oscillator grid will remain constant as long as the voltage wave extends from coil 1-2 of pulse transformer T1 to the closed end of FL-1 and back. After the reflected wave returns to the beginning of the FL-1 line there is a sharp decrease in voltage at the blocking oscillator grid and the tube cuts off until the next trigger pulse appears.

The duration of the resultant square-wave pulse depends on the parameters of the FL-1 forming line. It is equal to the time required for the voltage wave to travel through the line from its beginning its end and back, i.e., the time during which the blocking oscillator conducts.

A positive square-wave pulse of 0.8-μsec. duration and with an amplitude of about 370 v. is lifted from the output winding 5-6 of transformer T1 and fed to the control grids of the power amplifier.

Resistor R10 shunts the output winding of transformer T1 so as to weaken the oscillation processes in the circuit and reduce pulse shape distortion.

The submodulator power amplifier is assembled in a beam tetrode, GI-30 (V2). Both halves of the tube are connected in parallel and are cut off by the control grids biased at -200 v.

When a positive pulse from the blocking oscillator appears at the control grid, V2 unblocks and the current passing through the load winding 3-4 of transformer T2 creates a positive voltage with an amplitude of about 1000 v. at the output winding 5-6. This pulse controls the operation of the modulator (V3).

The L1R7 circuit corrects pulse shape of the submodulator. Resistors R5 and R6 are used to suppress parasitic oscillations in the grid circuits of the power amplifier.

From the step-down winding 1-2 of pulse transformer T2 the signal is brought out to the test plug P12, where an oscillograph may be connected for examining the pulse shape of the submodulator.

The modulator develops a negative square-wave video pulse with an amplitude of about 25 kv. which is fed to the magnetron oscillator.

Practically the modulator is a powerful electronic switch, feeding anode power to the magnetron for a duration of 0.8 μsec.

The GMI-90 (V3) modulator tube is the switching element. It is cut of by a -600 v. bias at the control grid. At this time the energy storage capacitors C9 and C10 charge to 27 kv. through resistors R17, R16, R15 and charging choke L2. After a positive pulse appears from the submodulator power amplifier, V3 unblocks and the condensers discharge through the tube and the magnetron, V5. The circuit uses two energy storage capacitors connected in series to reduce the possibility of breakdown due to the high plate voltage.

The internal resistance of the conducting modulator tube V3 is very small, and consequently almost all the voltage attained by the energy storage capacitors is applied to the cathode of the magnetron at a negative polarity. This voltage pulse causes the magnetron to generate high-frequency oscillations, which go to the antenna feeder system through the coupling element.

Resistors R16 and R16 limit the current of the 27-kv. high-voltage rectifier through the conducting modulator tube.

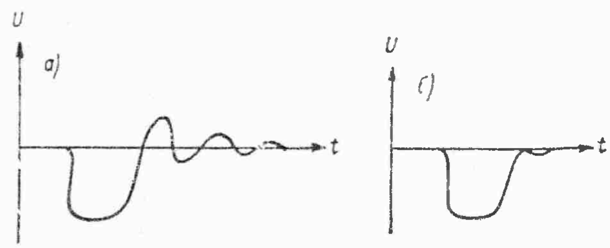

Fig. 9.4. Voltage charts at the diode V4
a) input, b) output

Chokes L2 and L3 and resistor R19 correct the modulator pulse shape.

A type VI2-70/32 suppressor diode (V4) quenches the positive overshoots (pulses) (Fig. 9.4) arising from parasitic oscillation in the circuit formed by choke L2 and spurious circuit capacitances. Because of the recharging of the capacitors in the circuit, several cycles of secondary oscillations appear after the main pulse has passed. The diode conducts the positive pulses and short-circuits them, significantly decreasing the number of overshoots.

The <u>magnetron oscillator</u> develops a powerful radio-frequency pulse in the 1770-1795-MHz range which is then fed to the antenna feeder system.

The oscillator consists of a MI-137 (V5) magnetron, positioned in the gap between the poles of a permanent magnet. The lines of force of the magnetic field should be parallel to the axis of the cathode.

The frequency of the magnetron is adjusted manually with the "Wavelength" knob located on the right-hand sidewall of the transmitter. Turning this knob mechanically adjusts the oscillation system of the magnetron, resulting in a change in the oscillation frequency.

The pulse power of the high-frequency oscillations generated is 200 kw. with a pulse duration of about 0.8 µsec.

Fig. 9.5 shows oscillograms taken at major points in the transmitter circuit.

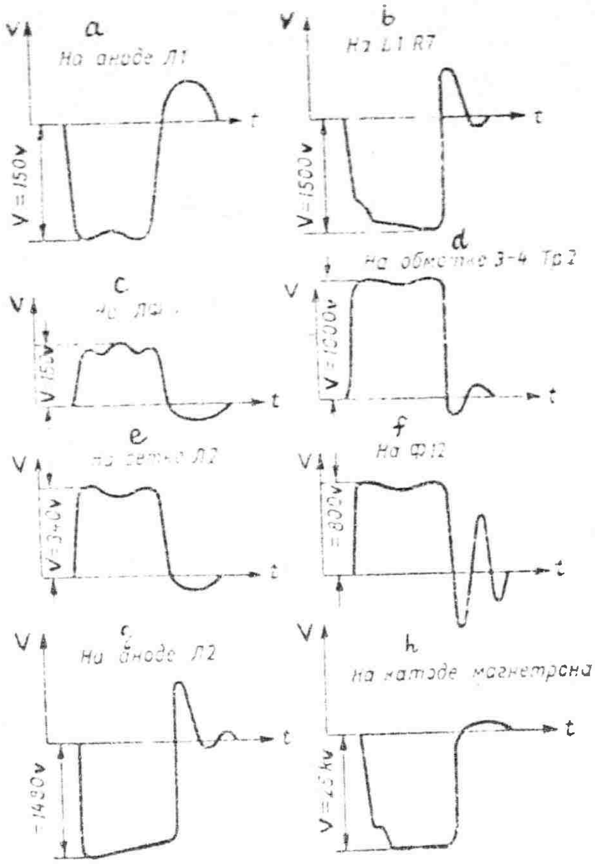

Fig. 9.5. Voltage shapes at major points in the MT-10
[Key on following page]

Key: a. To plate of V1
b. To L1R7
c. To FL-1
d. To winding 3-4 of T2
e. To grid of V2
f. To Pl2
g. To plate of V2
h. To magnetron cathode

Voltage sources. There are two rectifiers in the transmitting system, the modulator rectifier and the 27-kv. high-voltage rectifier. The modulator rectifier develops 2000 and 1400 d.c. volts for supplying the plate and screen-grid circuits of the tubes, and also -600 v. for biasing the control grids and feeding the time relay stage.

All rectifiers are single- or double-wave rectifiers with filtration of the voltage. Rectified voltage is checked using a needle-type measuring instrument, M-1 "Voltage Indicator," located on the front panel of the rectifier unit.

The current of all the rectifiers is checked using a needle-type instrument, M-2, "Rectifier Current."

The 27-kv. high-voltage rectifier is designed to feed the magnetron and is assembled as a separate unit. It is a voltage doubler using the P1-0,1/40 vacuum tube rectifiers. The voltage at the high-voltage rectifier is checked using the M-3 instrument, "Kilovolt," located on the front panel of the modulator rectifier unit.

A switch is used to select which voltage and current is to be checked; its knob is brought out to the front panel of the rectifier unit.

Control, blocking, and signaling circuits. Blocking, control, and signaling circuits are used to turn on the transmitting system in a specific sequence, to protect circuits from overloads, to protect maintenance personnel, and to indicate normal operation of the transmitter.

An electronic time relay is used to provide a 3-5-min. warm-up time for the cathodes of all tubes before the high voltage is turned on. After the power supply has been turned on, during this time the circuit is closed and it is impossible to feed high voltage to it. Moreover, an electronic relay makes it impossible to turn on the high voltage if the -600-v. rectifier is not working.

Maximum overload protection relays are included in the output circuits of the 2000-v., 1400-v., and 27-kv. rectifiers. These relays are adjusted so that if the total rectifier current exceeds the allowable limit the relay armature tightens and disconnects the rectifier power circuit (220 v.a.c.).

For high-voltage protection the transmitting system is equipped with a series of interlocks. When the transmitter door is opened, the access panel to the vacuum tube high-voltage rectifier removed, or the modulator rectifier unit pulled out from the cabinet, this breaks the interlock contacts connected in series in the rectifier supply circuit, and the high voltages are shut off.

Mechanical arresters are used to discharge the energy-storage and filter capacitors when the station is shut down. They automatically ground the discharge circuit of the energy-storage capacitors when the transmitter door is opened and the discharge circuit of the filter capacitors in the high-voltage rectifier when the access panel to the vacuum tube rectifiers is opened.

A series of indicator lamps on the front panel of the transmitter indicates when particular units are on and also their normal operation. Needle-type instruments are used for checking voltages and currents (as discussed above).

9.2. The MT-20 Antenna Feeder System

The antenna feeder system is designed to transmit high-frequency energy from the transmitter to the antenna and to transform it into electromagnetic oscillations emitted into space as a narrow beam. During transmitter pauses the system receives signals reflected from passive objects or active answering signals from a radiosonde and conducts them to the receiver input.

The antenna feeder system includes high-frequency coaxial feeders, rotating connectors, a T-junction, the antenna proper, and a discharge chamber (antenna switch). The block diagram of the antenna feeder system is given in Fig. 9.6.

The <u>high-frequency coaxial feeder</u> <u>4</u>, <u>6</u>, <u>8</u>, <u>12</u> is of rigid construction and is used to transmit electromagnetic energy from the magnetron to the antenna and from the antenna to the receiver.

The feeder consists of individual sections. Each section is composed of two coaxially placed brass tubes supported on quarter-wave metal insulators (Fig. 9.7). The diameters of the tubes are selected so as to allow passage of signals at the required power with the lowest possible losses in the feeder. Corner insulators (Fig. 9.8) are put at the bends of individual sections of the feeder; these are sections of quarter-wave lines shorted at the ends. Such lines have

infinitely great input resistance, as a result of which there is no leakage of power from the interior conductor to the exterior. The wide portion 5 of the interior conductor in the right-angle insulator is a quarter-wave transformer that matches the wave resistances of coaxial sectors 3 and 7 and decreases power reflection in the feeder line.

The rotating joints 5 and 7 (see fig. 9.6) insure passage of the signal from the transmitter to the antenna and from the antenna to the receiver by rotation of the antenna by azimuth and angle of elevation. Both joints are completely identical in construction. They consist of a movable and a non-movable portion. Rotation is carried out by means of two ball bearings.

The T-junction 9 (see fig. 9.6) is a transition device connecting the magnetron and the discharge chamber to the high-frequency feeder. One arm of the T-junction is connected to the high-frequency output of the magnetron, the second arm is attached through a loop coupler to the discharge chamber, and the third arm is connected to the feeder that goes to the antenna.

The antenna consists of a parabolic reflector 3, a filter 2, and an antenna head 1 (fig. 9.9). The reflector is a metallic mirror made in the form of a paraboloid of rotation. To save weight and decrease wind resistance (sail-like behavior), the surface of the paraboloid has a large number of openings. The diameter of the openings is so chosen that the reflecting capability of the mirror is not impaired.

The filter is a series of parallel metallic rods 2 placed horizontally in the aperture of the paraboloid. If the radiosonde transmitter antenna is not located in a vertical position, the horizontal component of the electrical field appears (fig. 9.10), impairing the stability of the antenna control system. The filter reflects the horizontal component and permits only the vertical component of the electrical field to pass.

The antenna head is located on the main optical axis of the parabolic reflector.

The structure of the antenna head is shown in fig. 9.11. It consists of a half-wave vibrator, a counter-reflector, a protective cap, a feeder section, and a counter-reflector rotation device. To the end of the feeder section is attached the half-wave vibrator situated vertically in relation to the horizon. This permits the radiation and reception of electromagnetic energy with vertical electrical field polarization.

The counter-reflector 2 is placed in front of the half-wave vibrator. It is a short circuited section of a circular waveguide (cup), on the sidewall of which are four asymmetrically cut out slits 3. The length of the slits is equal to half of the wave length.

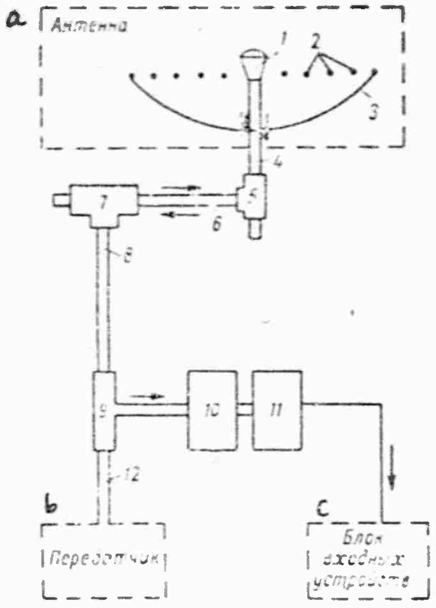

Fig. 9.6. Block diagram of the antenna feeder system.
1) Antenna head; 2) Filter; 3) Parabolic reflector; 4, 6, 8, 12) Feeder lines; 5) Rotating joint for swinging the antenna along the angle of elevation; 7) Rotating joint for swinging the antenna along the azimuth; 9) T-junction; 10) Antenna switch; 11) Mixer

Key: a. Antenna
b. Transmitter
c. Input device unit

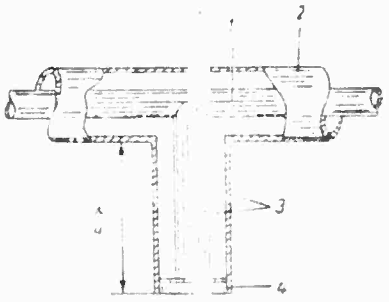

Fig. 9.7 A section of the feeder
1) Inner conductor; 2) Outer conductor; 3) Quarter-wave section; 4) Cap.

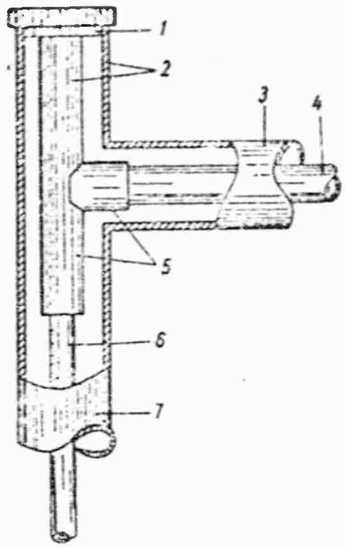

Fig. 9.8. Right-angle insulator. 1) Lid; 2) Quarter-wave section; 3,7) Exterior conductors; 4,6) Interior conductors; 5) Quarter-wave transformer.

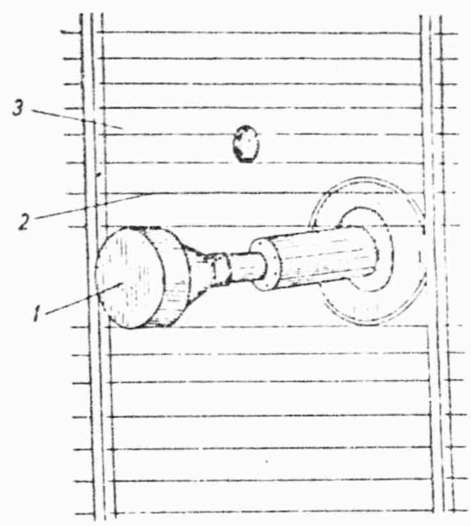

Fig. 9.9. Reflector and antenna head.

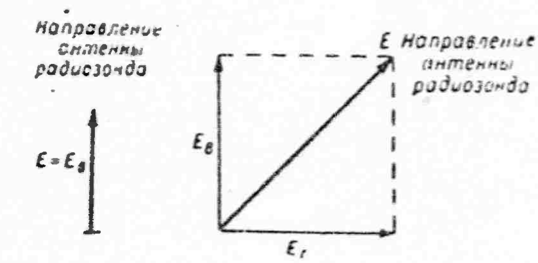

Fig. 9.10. Analysis of the vector of the electrical field when the radiosonde transmitter antenna is in a slanted position.

[Both inscriptions that the vector arrows in the figure point to say "Radiosonde antenna direction."]

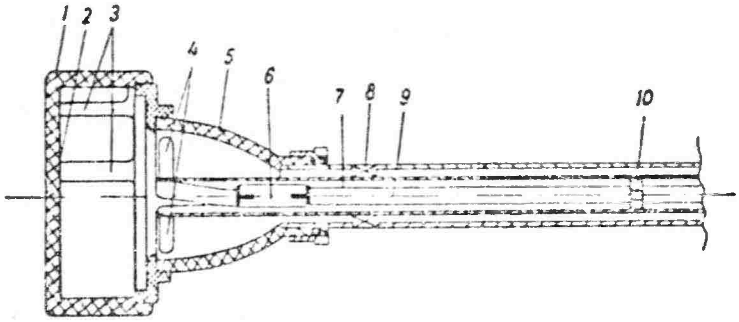

Fig. 9.11. Antenna head. 1) Plastic foam cap; 2) Counter-reflector; 3) Slits in the counter-reflector sidewall; 4) Half-wave vibrator; 5) Polystyrol cap; 6) Quarter-wave transformer; 7) feeder section; 8) Bearing; 9) Interior feeder section conductor; 10) Support collar.

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The counter-reflector reflects the energy emitted by the half-wave dipole 4 toward the paraboloid. The slots in the lateral surface of the housing are excited by the high-frequency currents, and, because the slots are positioned asymmetrically, the current of the reflected energy is mixed relative to the axis of the paraboloid. The result of this is that the parabolic reflector forms a narrow beam of electromagnetic energy whose axis is offset from the geometric axis of the paraboloid by 1.5-2°.

The counter-reflector is rotated by an electric motor with a constant angular speed of 24 r.p.s., resulting in conical scanning of the radiation pattern beam. The radiation pattern must be rotated in order to create an equisignal zone for automatic tracking along the angle coordinates. Since the dipole remains fixed, a vertical orientation of the electric component of the electromagnetic field is maintained.

The counter-reflector is placed in a foam plastic cover 1, which is screwed together with a conic polystyrene cover 5, which isolates the radiator and feeder section from the external surroundings.

The discharge chamber functions as an antenna switch. The crystal mixer (11, Fig. 9.6) of the receiver is rigidly connected to the chamber. A general view of the discharge chamber with the T-junction and mixer is given in Fig. 9.12.

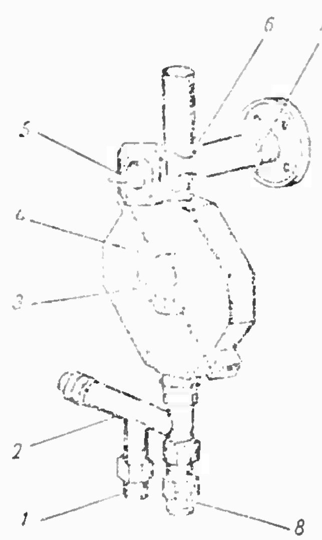

Fig. 9.12. Discharge Chamber
1) Heterodyne input; 2) Mixer; 3) Arrester regulating screw; 4) Cavity resonator; 5) Antenna input; 6) T-junction; 7) Magnetron input; 8) Output to i.f. preamp.

The discharge chamber is a collapsible cavity resonator containing a gas-discharge arrester with conical electrodes. The third (triggering) electrode of the arrester is fed -600 v. from the rectifier of the modulator. This voltage causes preliminary ionization of the gas in the discharge interval with the result that the arrester quickly breaks down during oscillation of the magnetron. The basic circuit of the antenna switch is given in Fig. 9.13.

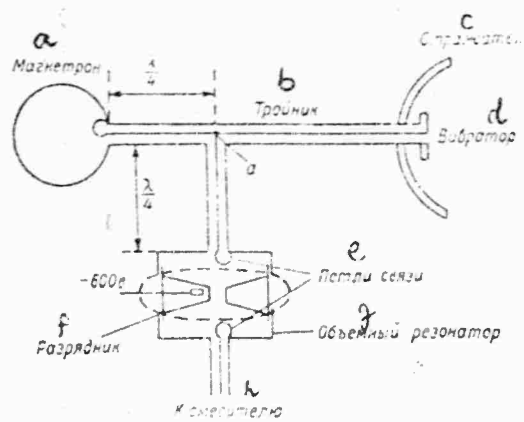

Fig. 9.13. Circuit of the antenna switch

Key: a. Magnetron
b. T-junction
c. Reflector
d. Dipole
e. Coupling loops
f. Arrester
g. Cavity resonator
h. To mixer

When the magnetron is operating part of the transmitter pulse energy goes through the coupling loop into the discharge chamber, causing rapid breakdown of the arrester. The internal resistance of the hot arrester is very small. The shoulder of the T-junction, which connects the feeder with the discharge chamber, is short-circuited. Since the length of this shoulder is equal to $\lambda/4$, the resistance at point a will be very great and all the high-frequency energy from the magnetron will be directed along the feeder to the antenna and radiated into the surrounding space. Since the internal resistance of the hot arrester is small, the voltage drop across it will also be very small. Consequently, when the transmitter is in operation the antenna switch will consume a minute amount of high-frequency energy to support the burning of the arrester. Some of this energy leaks through to the receiver and creates a mark of the sounding pulse on the indicator screen. When the transmitter stops

the arrester goes out and the Q-factor of the discharge chamber is increased.

If a reflected signal appears at the antenna input, it is fed to the discharge chamber through the coupling loop and excites the cavity resonator. An adjusting screw (Fig. 9.12) is used to tune the resonator (by changing its volume) to the frequency of the received signal. Both coupling loops are positioned at the antinodes of the magnetic field of the resonator. Maximum power take-off to the receiver input is achieved by rotating the coupling loop of the mixer.

High-frequency energy losses in the resonator are very small because of its large Q-factor. The energy of the received signal will not be shunted toward the magnetron since the quarter-wave segment of the shoulder of the T-junction is shorted at the end by the coupling loop. Since the oscillation system of the magnetron has its own frequency, which is not equal to the frequency of the oscillations generated, the reflected signal does not cause excitation of the magnetron resonators.

Thus practically all power from the incoming reflected or answering signal goes to the crystal mixer of the receiver.

9.3. The MT-30 Receiving System

The receiving system transforms the signals picked up by the antenna from a radiosonde or reflected from a corner reflector and amplifies them to a level necessary for normal operation of the range system, the antenna control system and the calculating system.

The receiving system includes a crystal mixer mechanically connected to the discharge chamber, a unit of input devices (MT-31), and a main amplifier (MT-32).

The receiving system can work in two modes: "Radiosonde" and "Corner Reflector."

In the "Corner Reflector" mode the reflected signal picked up by the antenna is fed along the feeder circuit through the discharge chamber to the crystal mixer connected to the discharge chamber by a flange.

The mixer consists of a segment of coaxial line with a coupling loop for connecting it with the discharge chamber. At the other end the line is loaded with a mixing element, for which a type D403-V crystal detector is used. The input resistance of the detector at a given frequency is matched with the characteristic impedance of the feedline, which allows maximum power of the received signal to be delivered to the mixer.

The lines of force of the variable electromagnetic field of the resonator intersect the coupling loop of the mixer in the discharge chamber. An electrodynamic coupling probe injects high-frequency oscillations (f_m) into the coaxial line of the mixer. In addition, the local-oscillator signal (f_h) is fed to the mixer through a probe. The power of the high-frequency signal from the local oscillator can be varied by changing the depth of insertion of the probe using the adjusting screw. As a result, a group of oscillations consisting of different combinations of oscillations with frequencies f_m and f_h appear on the mixing element. Oscillations of the difference frequency, $f_h - f_m$, also appear on it. This frequency is called the intermediate frequency and is adjusted to 30 MHz when the local oscillator is tuned. The basic amplification of the received signal takes place at this frequency.

A filter is included at the output of the mixer to filter higher frequency components out of the intermediate frequency.

From the mixer output the i.f. signals, which have the same shape as the signals picked up by the antenna, go through the high-frequency connector and are fed to the i.f. preamplifier in the unit containing the input devices.

The MT-31 input device unit consists of an i.f. preamplifier and a local oscillator. The unit is housed in the transmitter cabinet. The basic circuit of this unit is shown in Fig. 9.14.

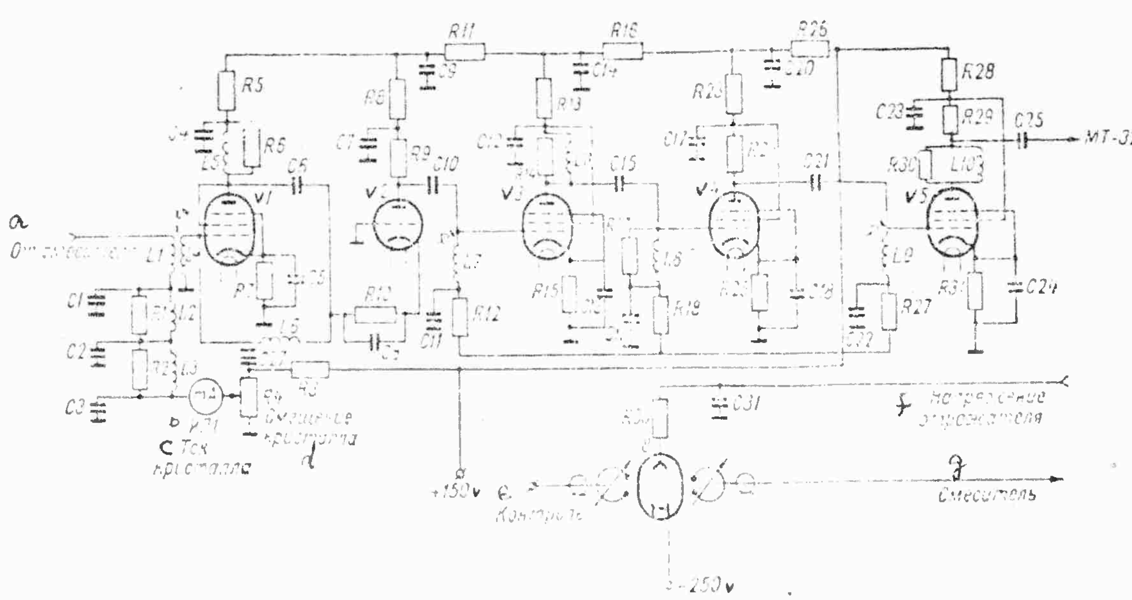

Fig. 9.14. Basic circuit of the MT-31

[Key on following page]

Key: a. From mixer
b. M-1
c. Crystal current
d. Crystal bias
e. Check
f. Repeller voltage
g. Mixer

The i.f. preamplifier consists of an input circuit and five stages of amplification. The input circuit includes an input network and a voltage filter for the crystal bias. The input network is formed by inductors L1 and L4 and the stray capacitances of the assembly and the tube V1.

The working point of the crystal mixer is selected by feeding a constant positive bias to it from the R3-R4 divider. The necessary voltage is established by potentiometer R4, "Crystal Bias." The value of this voltage should be optimal for the operation of the D403-V detector.

A milliammeter, "Crystal Current," is used for measuring the direct current in the crystal mixer and checking its operation.

Inductors L2 and L3 together with condensers C1, C2, and C3 form the high-frequency filter in the crystal mixer circuit. This filter does not pass i.f. signals to other stages of the unit. The d.c. component of the bias current passes from the source (the slider of potentiometer R4) through the milliammeter and coils L3, L2, and L1 to the crystal of the mixer.

To obtain a high amplification factor, a low noise level, and stable operation the first two stages of the i.f. preamplifier (V1 and V2) have a grounded-grid and grounded-cathode circuit. Negative feedback voltage is fed to the grid of the first stage through L6. The load of the first stage is formed by the network composed of L5 and the capacitance of the coil and stray mounting capacitance, and the load of the second stage is the network consisting of L7, stray mounting capacitance, the output capacitance of V2, and the input capacitance of V3. The networks are shunted by R6 and R9 to increase the pass band.

The third, fourth, and fifth stages are pentodes with identical resonance networks tuned to a frequency of 30 MHz. The load of the last stage is an oscillation network consisting of L10, stray mounting capacitance, the output of V5, and the capacitance of the cable connecting the MT-31 with the main amplifier unit, MT-32. In order to create a traveling wave, at the input of the main amplifier a load resistance of 75 ohms, which is equal to the cable impedance, is placed across the connecting cable. Amplification is controlled in the last three stages by feeding negative voltage to the control grids from the main amplifier unit.

A K41 reflex klystron (V8) is the local oscillator (heterodyne). It is designed to generate oscillations 30 MHz away from the frequency of the received signal. The oscillation system of the klystron is an external cavity resonator whose own frequency is varied by screwing in four tuning plungers which change the volume of the resonator. One of the plungers is mechanically coupled to a knob brought out to the front panel of the input device unit and labeled "Heterodyne Frequency." Coarse tuning of the frequency of the local oscillator in the specific range is effected with this knob.

The resonator of the klystron is grounded. A voltage of -250 v. is fed to the cathode. Voltage on the repeller of the klystron is made up of two stabilized voltages, -250 v. and -300 v. The -250 v. comes from the rectifier of the input device unit, and the -300 v. comes from the MT-80 power supply system for the main circuits of the receiving system and the calculation system. Both voltages go to divider R38-R42, which is in the main amplifier.

The potentiometers labeled "Repeller Voltage," "MFC Zone Selector," and "AFC Zone Selector," which are located in the MT-32 main amplifier unit, are used to adjust the voltage on the repeller within the limits of -(470-490) v. This is the voltage of the klystron oscillation zone.

Two coupling loops are used to pick off the high-frequency energy from the resonator. One loop is connected by a cable to the test socket labeled "Check," which is located on the front panel. The second loop transmits the local-oscillator signal through a cable to the mixer. The power of the output signal can be varied smoothly by changing the position of the loops in the resonator.

The MT-32 main amplifier is designed to amplify i.f. signals and transform them into video pulses which are used in the range, calculation, and antenna control systems. The basic schematic of the main amplifier unit is given in Fig. 9.15.

[This Fig. is included at the end of the translation.]

Fig. 9.15. Basic schematic of the MT-32

Key: a. Blanking pulse duration
b. Multivibrator
c. Amplifier
d. Limiter

[Key continued on following page]

e. Level of limiting
f. Frequency detector
g. D.c. amp.
h. AFC d.c. amp.
i. AFC gain
j. AFC
k. M-1
l. A.g.c.
m. AFC zone selector
n. AFC
o. MFC
p. MFC zone selector
q. Repeller voltage
r. Blanking pulse input
s. I.f. amp.
t. Detector
u. Video amp.
v. I.f. amp. input
w. CRCC gain
x. RRC gain
y. RC output
z. I.f. amp.
aa. Detector
bb. Video amp.
cc. A.g.c.
dd. UNG
ee. R a.g.c. gain
ff. ACRACC gain
gg. A.g.c. delay
hh. A.g.c.
ii. M.g.c.
jj. Gain
kk. A.g.c. zero adjust
ll. Amplifier
mm. Trigger
nn. Drop
oo. 800-kHz amp.
pp. Cathode follower
qq. 800-kHz amp.
rr. ARACC gain
ss. A.g.c.
tt. A.g.c. delay
uu. Detector
vv. Selector input
ww. Selector
xx. Multivibrator
yy. Cathode follower
zz. Operate

[Key continued on following page]

A. Calculate
B. Drop simulator
C. Selector bias
D. Output
E. Rack 1
F. Frame
G. GC 800 kHz
H. Rack 2
I. Frame
J. Neg. volt.
K. A.g.c.
L. Plug 6
M. Pulses to be counted
N. A.g.c. drop

From the output of the i.f. preamplifier the signal is fed to the control grid of V8 (6Zh5P). The stages assembled in V8 and V9 are the sixth and seventh i.f. amplifiers of the receiver system. They are tuned amplifiers using pentodes with identical oscillation networks in the control-grid circuits. The networks are formed by L6 and L7 and parasitic capacitances. Brass cores screwed into the coils are used to tune the circuit to 30 MHz. Resistors R43, R44, R45, and R50 shunt the networks, thereby increasing the pass band. Resistors R43 and R44 connected in parallel have a total resistance of 75 ohms, which is necessary for matching the circuit to the impedance of the cable connecting the i.f. preamplifier with the main amplifier.

After the second i.f. stage the circuit of the main amplifier is divided into a range channel (RC), an automatic corner-reflector control channel (ACRCC), and an automatic radiosonde-angle control channel (ARACC).

The <u>range channel</u> of the main amplifier is designed to amplify the i.f. signal and isolate and amplify the video signal and feed it to the range system. This channel operates identically in either the "Corner Reflector" or the "Radiosonde" mode.

The first and second stages in the i.f. channel (V10 and V11) are tuned amplifiers assembled in 6Zh5P pentodes. The networks containing L8 and L9 are tuned to 30 MHz.

Signal amplification is controlled in the second stage by relay P4 for each mode of operation. To attain the desired amplification the bias voltage is changed by changing the resistance in the cathode circuit. In the "Radiosonde" mode the amplification is set by a variable resistor, R60, "RRC gain," and in the "Corner Reflector" mode, by variable resistor R61, "CRRC gain."

From the plate load of the second i.f. stage the voltage is fed to the diode detector, D1 (D2V). Resistor R65 is the load of the detector. A filter, L10, C35, is used to prevent i.f. signals from

passing into the following stages. From the detector negative pulses go to the input of the video amplifier V12 (6Zh5P). The plate circuit of this stage includes a correcting choke, L11, which improves the frequency characteristics of the video amplifier in the high frequencies. Positive pulses of 50 v. are fed from the output of the video amplifier to the grids of the cathode followers, V13 and V14 (6P1P's). From the load resistor, R71, of V13 positive video pulses are fed to the automatic range-tracking unit, and from R75 they go to the range unit.

To provide a signal of constant amplitude into the range unit a diode limiter, D6, is used. The necessary reference voltage that determines the level of signal limiting is obtained from a divider, R190, R191, which is connected in the 150-v. supply circuit.

The automatic corner-reflector angle control channel is designed to amplify the i.f. signal, transform it into video pulses that control the automatic angle-coordinate tracking unit, and to isolate the a.g.c. voltage of the last three stages of the i.f. amplifier.

The signal goes from the plate load of the second i.f. amplifier of the range channel through C106 to the i.f. amplifier of the automatic corner-reflector angle control channel, which is a two-stage tuned amplifier (V18 and V19) with separate circuits.

The stage at V18 is common to the automatic corner-reflector angle control channel and the automatic radiosonde angle control channel.

In the "Corner Reflector" mode V18 is cut off at the screen grid by -10 v. taken from the R79-R81 divider in the -150-v. supply circuit. The circuit is unblocked by a positive 120-v. 0.5-μsec. ultranarrow gate (UNG) coming from the range unit. The UNG is developed in the range system at the moment a reflected signal appears. This causes an increase in the station's electronic anticountermeasures and its range resolution is improved.

In the "Radiosonde" mode the stage at V18 is normally conducting and is cut off by a negative blanking pulse applied to the screen grid from the stage at V2. The operating modes of V18 are switched by relay P6.

From the load resistor R87 the signal goes to the control grid of the stage at V19 and into the automatic radiosonde-angle control channel.

For each of the operating modes of the station the gain control circuits are switched by relay P5. The necessary amplification factor is set by changing the bias on the tube by adjusting the size of the cathode resistors R84, "R AGC Gain," and R85, "ACRACC Gain."

From the plate load R91 (of V19) the signal goes to the detector, D2, and into the automatic frequency control (AFC) circuit (V3). Resistor R94 is the load of the detector. A filter, L14-C54, is used to smooth the i.f. pulsations and to prevent the signal from feeding through into other stages. Negative pulses from the output of D2

smooth the i.f. pulsations and to prevent the signal from feeding through into the other stages. Negative pulses go from the output of D2 through C55 to the input of the two-stage video amplifier assembled in V20 (6Zh5P) and V21 (6P1P). Both stages operate as resistance-coupled amplifiers. The plate loads of the amplifiers are R96 and R101. Chokes L15 and L16 are connected in series with the load resistors to improve the frequency characteristics of the video amplifier. The amplification factor of the stages increases with an increase in frequency.

From the R101 load of the video amplifier (V21) a negative 70-v. signal is fed to the automatic gain control circuit (V22) and into the automatic angle-coordinate tracking unit (the antenna control system, MT-70).

In the "Radiosonde" mode the automatic corner-reflector angle control channel operates only into the common a.g.c. circuit. This circuit is designed to provide signals of approximately constant amplitude at the output of the receiving system despite large signal variations at the input. The gain of the receiving system can also be controlled manually.

The a.g.c. system reacts only to slow changes in the signal, which are brought about by a change in the distance to the object or by prolonged fading of the signal; it does not react to the rapid signal changes caused by the conic scanning of the radiation pattern beam.

When an incoming signal increases in amplitude the a.g.c. circuit develops a negative bias voltage, which is fed to the grids of the third, fourth, and fifth stages of the i.f. preamplifier, and their amplification factor is automatically reduced.

From the R91 load of the video amplifier the signal goes to the a.g.c. detector, the left half of V22 (6N1P), which is connected as a diode. A small negative voltage taken from the R109-R110-R112 divider is applied to the plate of the detector. The divider is connected to a -150-v. source. When there is no signal the current in the detector is zero and there will be no voltage drop across its loads, R107 and R111.

A positive a.g.c. delay voltage of 40 or 50 volts is fed from the 150-v. voltage source to the cathode of the a.g.c. detector through R105 and R106. This voltage is needed to prevent the a.g.c. circuit from reacting to weak signals. Its operation is delayed as long as the negative signal at the output of the a.g.c. detector does not exceed the delay voltage. In this case current flows through the detector and C61 begins to charge through V22 and R105 and R106. After the signal stops C61 discharges through R111, R107, and R112.

The negative voltage arising from the discharge of the capacitor is picked off from R107 and R112 and fed to the grid of the cathode follower. The cathode follower of the a.g.c. circuit is a typical one in the right half of V22. The R108 load resistor of the cathode follower is selected so that in the absence of signals the voltage at the cathode is approximately zero. Precise setting of zero is made with potentiometer R112, "AGC Zero Set." A circuit including R107, R112, C63, and C64, which determines the time constant (2.3 sec.) of the discharge circuit of C61, is included in the grid circuit of the cathode follower. Since the value of the time constant is large, the a.g.c. circuit cannot react to rapid changes in the amplitude of incoming signals.

Increase of an incoming signal leads to an increase of the negative potential at the grid of the cathode follower and causes a change in the d.c. voltage at the R108 load resistor. This voltage is fed to the i.f. preamplifier and, applied to the control grids of V3, V4, and V5 of the MT-31 unit, it changes the amplification factor of the whole receiving system.

To protect the a.g.c. circuit from pulse interference in the "Radiosonde" mode, at the input of the a.g.c. detector a filter is connected which consists of L22, C116, and C117. The filter is tuned to 800 kHz. The pulse noise is differentiated and grounded to the frame through the L22-C117 network, since this network has very little resistance to it. The 800-kHz signal from the output of the video amplifier (V21) is not diverted by the filter and passes to the a.g.c. detector. This network is required because the a.g.c. circuit is not gated in the "Radiosonde" mode. The filter is switched by relay P7.

Switch B1, "AGC-MGC," switches the gain control from automatic to manual. For manual control of the total amplification switch B1 is in the MGC position. In this case the potential at the grid of the cathode follower will depend on the position of the arm of variable resistor R110, "Gain."

In the "Radiosonde" mode signals picked up by the antenna go through the discharge chamber to the crystal mixer, then to the i.f. preamplifier, the i.f. stages, and into the range channel of the main amplifier. In the "Radiosonde" mode these stages operate just as in the "Corner Reflector" mode, but the signals at the output of the range channel are a series of 800-kHz video pulses alternating with 50-300 µsec. pauses. The answering signal from the radiosonde is an 800-kHz video pulse of increased amplitude and a 1-1.5-µsec. pause following it.

From the output of the last i.f. amplifier stage of the main amplifier (V9) the i.f. signal goes to the gated stage of the i.f. amplifier (V18) of the automatic corner-reflector angle control channel This stage functions in both modes of operation.

In the "Radiosonde" mode the stage is normally conducting and is blanked (cut off) by a negative pulse with an amplitude of 130 v. and a duration of 30-130 μsec., which is fed to the screen grid of V18. The blanking pulse is designed to block the automatic corner-reflector angle control channel and the automatic radiosonde-angle control channel during the transmitter sounding pulse and the powerful pulses reflected from local objects.

Positive 833-Hz and 100-μsec. pulses are formed in the transmitter trigger channel of the range system; these pulses lead the transmitter triggering by 20-50 μsec. They go through C1 to the flip-flop multivibrator at V1 (6N1P) and trigger it. The multivibrator functions as a blanking pulse oscillator.

Potentiometer R2, "Blanking Pulse Duration," controls the duration of the blanking pulse within a range of 30-130 μsec. The blanking pulse anticipates the transmitter triggering pulse by 15-20 μsec.

From the output of the multivibrator the blanking pulse is fed to the amplifier at V2 (6N3P). Amplification is necessary because in the operating mode the voltage at the screen grid of V18 is +120 v. A negative pulse with an amplitude no less than 130 v. must thus be fed to the screen grid to cut off the tube. This pulse is taken from the blanking pulse amplifier and goes through the contacts of relay P6 to the screen grid of V18. From the output of V18 the i.f. signal goes to the automatic radiosonde-angle control channel and the automatic corner-reflector angle control channel.

The automatic radiosonde-angle control channel is designed to isolate and transform the 800-kHz signal from the radiosonde, amplify it, maintain a constant amplitude at the output and transmit this signal to the automatic angle-coordinate tracking unit, and also to form the a.g.c. voltage drop which is used in the receiving system and the counting system for forming the count pulses.

The automatic radiosonde-angle control channel includes an automatic angle-control circuit in the "Radiosonde" mode, the 800-kHz automatic gain control, the automatic threshhold device circuit, the circuit for forming the pulses to be counted that contain meteorological data, and the automatic frequency control circuit.

1. In the "Radiosonde" mode the automatic angle-control circuit consists of a detector, D4 (D2V), a two-stage 800-kHz amplifier at V23 and V24 (6K4P), and a cathode follower, V25 (6Zh5P).

The i.f. signal goes from the output of V18 to the detector operating as a diode detector of the weak signals. The amplitude of the signal voltage at the input of the detector is 0.1-0.2 v. To prevent the i.f. signal from feeding through to the amplifier a filter is used, C15, L21, and R171.

The first 800-kHz stage of the amplifier (V23) is assembled in a typical pentode circuit with a two-stage bandpass filter. The plate load is a resonant circuit, L17, C67, and C112, which is tuned to 800 kHz, the first harmonic of the repetition frequency of the radiosonde transmitter super noise. The second stage (V24) is assembled with a single resonant network in the plate circuit, which is tuned to 800 kHz.

The 800-kHz signal goes from the plate load of V24 through C75 to the cathode follower (V25, 6Zh5P) and to the 800-kHz a.g.c. circuit (V26). The voltage taken from the cathode load can be controlled within the limits of 0 to 1.5 volts by potentiometer R123, "ARACC Gain." This voltage goes from the output of the cathode follower to the automatic angle-coordinate tracking control unit in the antenna control system (MT-70).

2. The 800-kHz automatic gain control circuit is designed to maintain this signal at a constant level despite extensive fading of the radiosonde signal. The a.g.c. circuit includes an 800-kHz amplifier, V26 (6K4P), an a.g.c. detector (the left half of V27), a cathode follower (the right half of V27), and a level limiter (the left half of V28, a 6N3P).

The 800-kHz amplifier is a tuned amplifier with a single tuned circuit in the plate circuit (V26). The signal goes from the plate load of V26 through C81 to the 800-kHz a.g.c. detector (the left half of V27), which is a diode detector with parallel connected load. The load is a chain of resistors, R128, R123, and R134. Resistor R134 is the cathode load of the left and right halves of the tube.

In the absence of a signal from the radiosonde a small negative voltage is isolated at the load, owing to the detection of internal receiver noise. It is lifted from R129 and fed to the grid of the cathode follower (the right half of V27). This voltage determines the size of the current flowing through the cathode follower. The current creates a voltage drop across the common load resistor, R134.

When signals from the radiosonde are present the negative voltage at the output of the detector is increased, and, consequently, so is the voltage at the grid of the cathode follower. A change in the amplitude of the incoming signals also results in a change in the bias on the grid of V27. The larger the negative voltage appearing on the grid of the cathode follower, the smaller is its current and the smaller is the potential at the load, R134.

From R134 the voltage is fed to a divider, R130, R131, and R133. This divider is connected in the +150-v. supply voltage circuit, and the positive source voltage and the negative voltage from the output of the cathode follower are summed on it. The summed voltage is taken from R133 and fed to the control grid of the d.c. amplifier stage (V31) for the purpose of controlling the threshhold device. At the same time

the voltage falling across the divider is taken from potentiometer R131, "AGC Delay," and fed to the limiter (the left half of V28) and through the R125-C82 filter and R117 and R118 to the control grids of V23 and V24 of the 800-kHz amplifier. The level of voltage limiting is selected by potentiometer R131. The a.g.c. begins to operate only when the negative voltage from the output of the cathode follower is greater than the positive potential used to unblock the diode limiter.

If there is no signal from the radiosonde or if its magnitude is less than the a.g.c. delay voltage, a positive voltage is fed from the slide of potentiometer R131 through R132 to the plate of the left half of V28. The limiter conducts, and all the voltage drops across R132 and does not appear at the grids of the 800-kHz amplifier tubes. Thus the voltage on the control grids of V23 and V24 is fixed at a zero level.

When a signal appears the voltage from the output of the cathode follower is greater than the delay voltage, the diode limiter cuts off, and the control signal goes to the grids of V23 and V24, resulting in a change in the amplification factor of the automatic angle-control channel.

The time constant of the automatic gain control circuit is determined by the values of C82 and R125 and is equal to approximately 0.75 sec.

3. The circuit of the threshhold device (Fig. 9.16) consists of a d.c. amplifier (V31), a trigger (V32), a cathode follower (the left half of V5), and a limiter (the right half of V5).

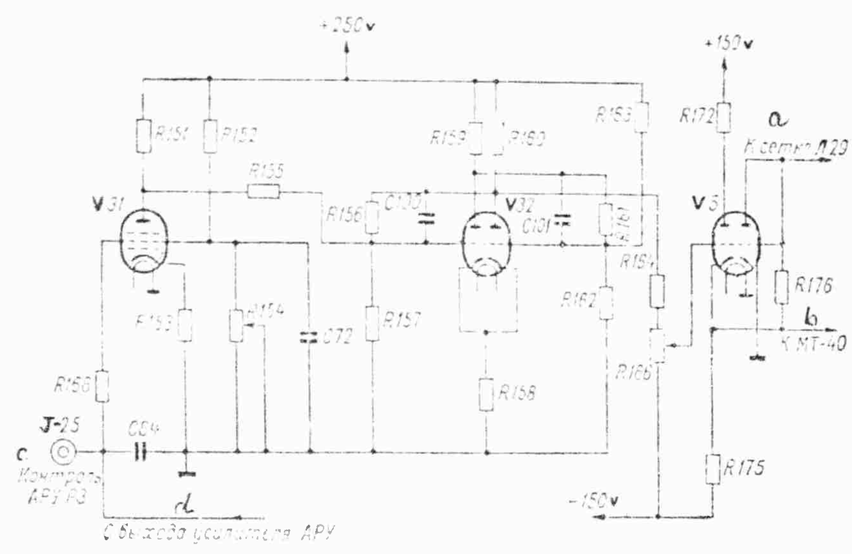

Fig. 9.16. Schematic of the threshhold device

[Key on following page]

a. To grid of V29
b. To MT-40
c. Radiosonde a.g.c. test
d. From output of a.g.c. amp.

When there is extensive signal fading the circuit develops a blocking voltage which is fed to the counting system and controls the memory unit in the counting of pulses carrying meteorological information. When the fading stops, the count is resumed and continues until the total count time is equal to that determined by the operator during the operation of the station.

When there is no radiosonde signal the voltage controlling the threshhold device is taken from R133 and fed to the control grid of the d.c. amplifier (V31). The tube conducts and a large grid current appears in it which causes the drop of almost all the control voltage at R168, and the potential at the control grid of V31 approaches zero. The voltage at the plate of the conducting tube will also be small; its magnitude is less than the potential at the grid of the trigger (V32). The plate of the tube is connected with the grid of the trigger through R155. The result of this is that the left half of the trigger is cut off and the right half conducts.

The small positive voltage goes from the plate of the conducting half of the trigger to the voltage divider consisting of R164 and R166. The divider is connected to a -150-v. source. In the absence of signals from the radiosonde the total voltage at the divider is negative (-50, -60 v.); from the slider of potentiometer R166 the drop voltage goes to the grid of the cathode follower (V5).

When a signal from the radiosonde is present the d.c. amplifier tube cuts off and the trigger fires. The result of this is that the potential of the plate of the right half of the trigger increases and the drop voltage at the R164-R166 divider becomes smaller (-14, -16 v.)

The potentiometer R166, "Drop Level," is used to set the drop voltage level (-14, -16 v.) when a radiosonde signal is present.

Condensers C100 and C101 connected between the plates and the grids of the trigger increase the steepness of the drop voltage fronts. Potentiometer R154 regulates the amplification factor of the d.c. amplifier.

The right half of V5 functions as a limiting diode. If a positive voltage appears at the output of the circuit forming the pulse drops, the diode conducts, shorting it to ground; hence the positive pulse does not reach the pentode grid of the selector (V29). From the R175 cathode load the drop voltage goes to the counting system.

4. The circuit that shapes the pulses to be counted that contain meteorological data consists of a detector (the right half of V28), a selector (V29), a separation diode (D3), and a flip-flop multivibrator (V30).

From the 800-kHz amplifier (V26) the amplified signal is fed to the pulse-counting detector (the right half of V28), which is a plate detector (cf. Fig. 9.15). The positive video pulses go from the output of the plate detector through the R141-C88 integrating circuit and switch B4 to the control grid of the selector (V29).

The operation of the selector is controlled by potentiometer R138, "Selector Bias," which is part of the divider consisting of R135 and R138 and which creates a negative bias voltage on the control grid of the selector.

The selector stage is blocked at the pentode grid by a negative drop voltage during deep fading of the radiosonde signal. When radiosonde signals are present no drop voltage is created, the selector tube conducts, and negative video signals go to trigger the flip-flop multivibrator through the separation diode, D3. The separation diode decouples the selector stage and the flip-flop multivibrator and shortens the time required for the multivibrator to return to its original condition.

The multivibrator forms the 120-μsec. count pulses, which go from the plate of the right half of V30 through C93 to the counting system. The pulse repetition frequency of the multivibrator corresponds to the frequency of the active pauses in the radiosonde signal.

In the circuit there is provision for checking the operation of the counting system. When switch B4 is in the "Check Count" position, 1000-Hz check pulses are fed to the control grid of the selector from the electronic pulse-count indicator unit (the counting system).

Pressing the knob of switch B5, "Drop Simulator," closes the circuit and a voltage drop is simulated which is similar to the drop that occurs when the radiosonde signal fades.

5. The automatic frequency control circuit consists of an amplifier/limiter, V3 (6Zh2P), a frequency detector, V4 (6Kh2P), a d.c. amplifier, V7 (6Zh5P), and a d.c. amplifier for the indicator device, V6 (6Zh2P) (cf. Fig. 9.15).

The i.f. signal goes from V19 through C50 and R3 to the control grid of V3, which provides normal operation of the frequency detector (V4). The desired gain of V3 is established by changing the bias voltage using potentiometer R23, "AFC Gain." The limiting level of the stage is set by changing the size of the plate resistor, R19, "Limiting Level."

The output of the stage is connected through C7 to the primary winding of the discriminator transformer, T1. The secondary of this transformer is connected to the plates of the frequency detector (V4). The parameters of the frequency detector are selected so that if the i.f. frequency is less than the frequency to which the circuits in the receiving system are tuned, a positive voltage with respect to the voltage on the repeller of the klystron (the local oscillator) is taken from the load resistors R27 and R28 of the discriminator, and vice-versa. This is called the mismatch voltage and its magnitude is proportional to the change in the radiosonde signal frequency.

From the output of the frequency detector the mismatch voltage is fed to the d.c. amplifier, the frequency control amplifier (V7), and the error-frequency control amplifier (V6).

From the output of V7 the amplified voltage goes through relay P3 and switch B2 to the repeller of the MT-31 klystron and changes its oscillation frequency so that the i.f. frequency is equal to 30 MHz.

In the AFC mode the zone of oscillation of the klystron is selected by changing the operation of V7 in the screen-grid circuit. Potentiometer R40, "AFC Zone Selector," is used for the coarse tuning, and potentiometer R38, "Repeller Voltage," is used for the fine tuning.

Provision is made in the main amplifier unit for manual frequency control (MFC) by changing the voltage on the repeller of the klystron. In this case the d.c. amplifier (V7) is disconnected from the circuit by switch B2 and replaced by a voltage divider, R170, R42, and R38. Voltage is taken from this divider to the repeller of the klystron. Potentiometer R42, "MFC Zone Selector," controls the coarse tuning of the klystron oscillation frequency, and potentiometer R38, "Repeller Voltage," controls the fine tuning.

The AFC system operates only in the "Radiosonde" mode. In the "Corner Reflector" mode relay P3 cuts out the AFC circuit.

Measuring instrument M-1, a microammeter with zero in the middle of the scale, is used to check the amount of frequency detuning of the detector. The meter is connected in the plate circuit of the d.c. amplifier (V6). The operation of the amplifier is adjusted so that the needle reads zero at a frequency equal to the frequency to which the i.f. circuits have been tuned. The zero set is effected by potentiometer R34 when there is no radiosonde signal and the receiving system is at its maximum working gain.

The measuring instrument is also used to check the 800-kHz a.g.c. amplifier voltage.

Switch B3 should be in the AFC position for checking the operation of the automatic frequency control circuit.

9.4. The MT-40 Count System

The count system is designed to count the number of radiosonde pulses during a specified time interval, called the count time. In addition, the count system synchronizes the operation of the systems of data transmission and recording and produces a visual indication of the counted pulses for checking the operation of the count system.

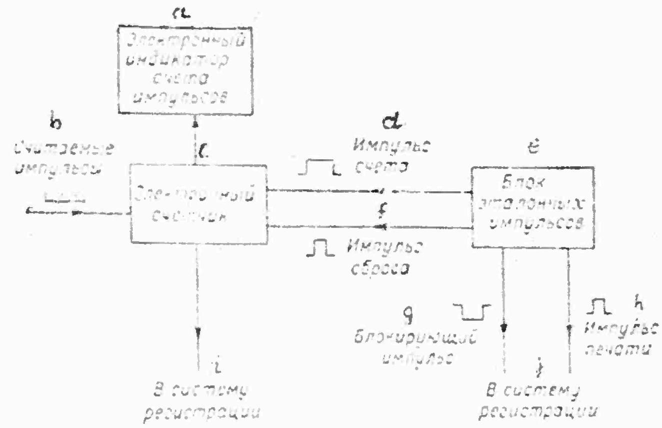

Fig. 9.17. Block diagram of the MT-40 count system

Key: a. Electronic pulse-count indicator
b. Pulses to be counted
c. Electronic recorder
d. Count Pulse
e. Reference-pulse unit
f. Reset pulse
g. Blocking pulse
h. Print pulse
i. To recording system
j. To recording system

The system can work with either a fixed or a variable count time. With a fixed count time (absolute count) the number of pulses entering the pulse counter during 1 sec. is counted. When the variable count time (relative count) is used, the count time can be varied from 1.04 to 1.128 seconds.

When the radiosonde signals fade the count stops and the number of pulses counted up to the moment of fading are recorded by the counter. Simultaneously the time during which the pulses were counted is recorded. After the radiosonde signals begin again the count is resumed and continues until the total count time reaches the established value (1 or 1.04-1.128 sec.).

The operation of the count system controls the threshhold device in the main amplifier unit.

The count system incorporates a reference-pulse unit, an electronic pulse counter, and an electronic pulse-count indicator.

A simplified block diagram is given in Fig. 9.17.

The reference-pulse unit is designed to synchronize the operation of the electronic recorder and the meteorological data recorder. The unit includes circuits for forming the count pulses, the print pulses, the reset pulses, and the blocking pulse.

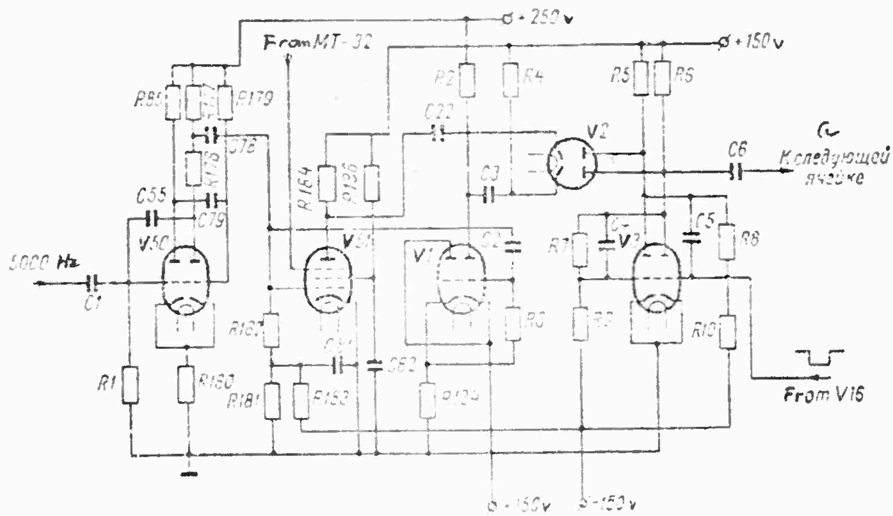

Fig. 9.18. Count-pulse forming circuit

Key: a. To next cell

The count-pulse forming circuit consists of a multivibrator, selectors, four frequency dividers with a total division coefficient of 25,000, a sanatron, and a count-pulse generator. The circuit containing the multivibrator, the selectors, and one stage of the frequency divider is given in Fig. 9.18.

Pulses of a stable repetition frequency of 5000 Hz and a duration of 0.2 μsec. are fed from the range unit through C1 to the flip-flop multivibrator (V50); the multivibrator forms 5000-Hz pulses with an extended duration of 50 μsec.

From part of the multivibrator plate load (R178) positive 50-μsec. pulses go to the control grid of the first selector (V51). The negative bias voltage for the selector is taken from the R182-R183 divider. The drop voltage is fed to the suppressor grid of V51 from the main amplifier unit (from the threshhold device). During radiosonde signal fading -50 v. is fed to the suppressor grid of V51 and cuts it off. The result is that the 5000-Hz pulses do not pass through the selector. When radiosonde signals are present the voltage at the screen grid is zero, the pentode V51 conducts, and pulses from the multivibrator trigger the frequency divider.

The second selector is assembled in the right half of V1. Its function is to provide 5000-Hz pulses triggering the dividers continuously except for the time during which the pulse counter is in operation. Positive pulses from the output of the multivibrator are fed through C1 and C78 to the control grid of the selector. The left half of V1 is a cathode follower, and the drop voltage at its load, R124, is applied through R3 to the control grid of the selector. In the absence of count pulses the voltage at the grid of the right half of V1 is 145 v., i.e., with respect to the cathode of the tube it is approximately equal to -5 v. The selector in this case conducts and the 5000-Hz pulses trigger the divider circuits.

If a negative count pulse is fed from the count-pulse generator to the grid of the cathode follower, the plate current of the left half of V1 sharply decreases. The voltage on R124 and, consequently, the voltage on the grid of the second selector, falls to -105 v., the tube is cut off, and the pulses from the multivibrator cannot reach the input of the divider circuit.

Voltage curves explaining the operation of the selectors are shown in Fig. 9.19.

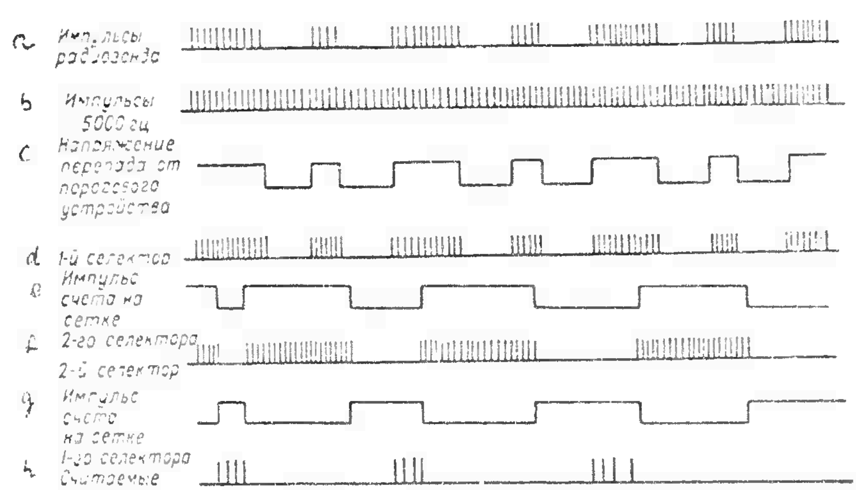

Fig. 9.19. Voltage curves in the selectors

[Key on following page]

Key: a. Radiosonde pulses
b. 5000-Hz pulses
c. Drop voltage from threshhold device
d. First selector
e. Count pulse at grid of second selector
f. Second selector
g. Count pulse at grid of first selector
h. Counted pulses

The use of two parallel selectors provides for stopping the count-pulse formation when the time of the fading coincides with the count time.

From the output of the selectors 5000-Hz pulses are fed to the circuit containing the dividers (V3-V47) and trigger them. A binary counting cell (trigger) is the divider with two stable equilibrium states. Each cell is assembled in a twin triode, V3, and a switching diode, V2 (cf. Fig. 9.18). Bias voltage is fed to the grid of the triodes from the R9-R10 divider in the -150-v. power supply.

In the stable state the plate voltage of the cut-off trigger is 145 v. and the plate voltage of the conducting trigger is 45 v. Both V2 switching diodes are cut off, since their cathodes are fed +150 v. which in amplitude is higher than the potential of each of the plates of the V2 diodes.

When a negative trigger pulse with an amplitude of about 30 v. is delivered to the cathodes of the diodes, the potential at the cathodes becomes 120 v. The switching diode whose plate is connected with the plate of the cut-off triode unblocks, and a negative pulse passing through R8 (cf. Fig. 9.18) to the grid of the right-hand conducting triode cuts it off. The positive voltage from the plate of this triode goes to the grid of the cut-off triode and unblocks it. The circuit passes to the second stable state, in which the right triode is cut off and the left conducts. The next negative trigger pulse returns the circuit to its initial state.

The frequency of the rectangular pulses formed at the plate load will be half that of the trigger-pulse frequency. Thus each trigger cell is a 2:1 frequency divider.

The negative pulse from the output of the cell triggers the next trigger, etc. The remaining counting cells operate similarly.

The division coefficient of the entire system of dividers is 25,000. This coefficient is necessary to obtain count pulses with a recurrence period of 5 sec. (a frequency of 0.2 Hz). Therefore the division coefficient should be:

$$K = \frac{5000}{0.2} = 25,000$$

Thus, 25,000 pulses with a repetition frequency of 5000 Hz must appear at the input of the divider circuit in order to form one count cycle.

If, for example, 1000 pulses have appeared at the input of the divider circuit, and then the incoming pulses have stopped because of radiosonde signal fading, the divider circuit remains in a stable state corresponding to the 1000 pulses that have been transmitted to its input and will remain in this state until the 5000-Hz pulses at its input are renewed.

The formation of the count cycle ends after 25,000 - 1000 = 24,000 pulses have appeared after the radiosonde signal first faded.

Thus the total count time is maintained, although the duration of the pulse count here will be increased by the time during which the signal was not being received. The count stops during the time in which there are no radiosonde signals, but the counter stores the number of pulses that passed into it up until the moment of fading. When the fading comes to an end the first selector unblocks and the circuit finishes forming the pulse count.

Pulses with a frequency of 0.2 Hz and a duration of 1 sec. are taken from the output of the last divider. These pulses go through the switching diode to the input of the count-pulse generator and into the sanatron circuit. The count-pulse generator is a trigger which is fired by the leading edge of a pulse whose duration is 1 sec. In the absolute-count mode the trigger is cut off by the trailing edge of this pulse. Thus, in the absolute-count mode the generator develops pulses with a duration of 1 sec.

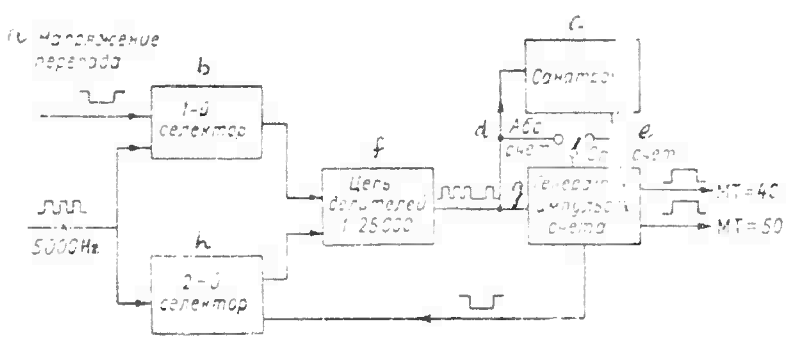

Fig. 9.20. Block diagram of count-pulse formation

[Key on following page]

Key: a. Drop voltage
b. First selector
c. Sanatron
d. Absolute count
e. Relative count
f. 1:25000 divider circuit
g. Count-pulse generator
h. Second selector

In the relative-count mode the negative cut-off pulse goes to the trigger through a linear delay circuit (the sanatron). In this mode the duration of the generator pulse is made up of the duration of the second pulse and the delay time of the sanatron pulse, which can be varied between 0.04 and 0.128 sec. The duration of the count pulse can be varied between 1.04 and 1.128 sec.

The formed count pulse with an amplitude of about 100 v. goes to the electronic counter selector and into the range unit for blocking the transmitter triggering during the count time. Simultaneously the count pulse goes to the grid of the cathode follower of the second selector (V1) in order to prevent pulses from appearing at the input of the dividers during the count pulse operation.

The block diagram of the count-pulse formation is given in Fig. 9.20.

The circuit forming the print, reset, and blocking pulse. The print pulse should be developed in the circuit four seconds after the beginning of the count cycle. From one of the stages of the last divider the pulses go through the selector to the print-pulse generator, which is a phantastron with cathode coupling. A 0.3-0.5-sec. print pulse, delayed by 4 sec. relative to the leading edge of the pulse, is formed at the output of the phantastron. This pulse is fed to the recorder unit (MT-60) to actuate the printing electromagnets. The print pulse goes simultaneously to the reset-pulse generator, which is a flip-flop multivibrator with cathode coupling. The multivibrator develops a negative reset pulse with a duration of 0.3-0.5 sec., which is delayed relative to the leading edge of the count pulse by approximately 4.5 sec. The reset pulse causes the relay to trigger, which takes the voltage from the grids of the triggering cells of the electronic counter and returns it to its initial state. This leads to a "cleansing" from the counter's memory of all pulses that have entered it up to this point.

To prevent the printing of false points which may appear because of movement of the type-setting electromagnets, the print circuit of the recorder unit is blocked. The blocking pulse is developed by the trigger circuit, which is actuated by the trailing edge of the print pulse; it arises 0.5-0.7 sec. before the count pulse and operates

for 1.75-1.95 sec. During the time the blocking pulse is present the counter is reset, the number of radiosonde signals during the count time is counted, and the results of this count are printed out by the electromagnets.

Fig. 9.21 shows the voltage relationships relative to time in major circuits of the reference pulse unit.

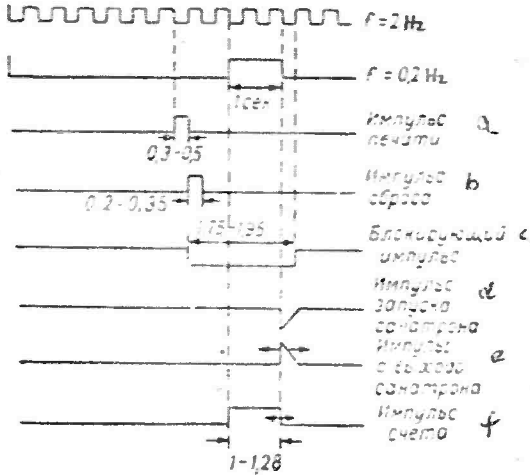

Fig. 9.21. Voltage relationships relative to time in the reference-pulse unit

Key: a. Print pulse
b. Reset pulse
c. Blocking pulse
d. Sanatron trigger pulse
e. Pulse from output of sanatron
f. Count pulse

<u>The electronic pulse counter</u>. The electronic pulse counter is designed to count the number of radiosonde pulses for a specific time interval and to transmit the results of the count to the recorder. The recorder contains a pulse selector and four count decades with intermediate thyratron stages.

<u>The selector</u>. Depending on the mode of operation (absolute or relative count) the input of the recorder should be open for either 1 sec. or 1.04-1.128 sec. for counting the pulses carrying meteorological information. This is accomplished by the selector stage assembled at V32 (cf. Fig. 9.25). In its initial state the selector tube is cut off by +150 v. delivered to the cathode. When a count pulse arrives from the reference-pulse unit the potential at the control grid of the tube increases to 142 v. and the positive pulses to be counted unblock the tube. Negative pulses are formed in the plate circuit of the selector which go to the input of the first counting decade of the electronic counter.

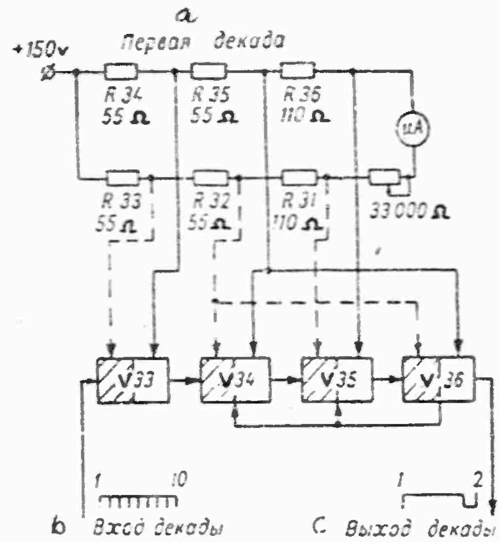

Fig. 9.22. Block diagram of the counting decade with control devices

Key: a. First decade
b. Input
c. Output

The counting decades are dividers that decrease by a certain number of times the number of pulses operating at the input.

The counter consists of 14 counting trigger cells, assembled in four counting decades of units, tens, hundreds, and thousands. Three decades are complete, and their total division coefficient, K_1, is $10 \times 10 \times 10 = 1000$, and one is incomplete, its division coefficient being $K_2 = 4$. The total division coefficient of the circuit is $K = K_1 \times K_2 = 4000$. The number of pulses that the circuit can count is $K - 1 = 3999$. The last (four thousandth) pulse returns the entire system to its original state.

The number of pulses arriving at the counter input is determined by the electrical state of all 14 cells of the counting circuit. Each complete counting decade consists of four triggers and is assembled in a circuit similar to the divider circuit in the reference pulse unit. A decade has 10 stable equilibrium states. Each cell is triggered sequentially from one to the next through the switching diodes. Each of the ten pulses appearing at the input of a decade corresponds to a specific combination of trigger states.

A control instrument and measuring resistors are used to measure the number of incoming pulses.

The block diagram of a complete counting decade with the connected control instruments is shown in Fig. 9.22. (On the schematic lines have been drawn through the halves of the trigger tubes which are cut off.)

The measuring resistors are connected in the decade so that a specific voltage drop across the resistors corresponds to each of the stable equilibrium states. This voltage is measured by a control instrument located in the recorder unit.

The circuit of measuring resistors (Fig. 9.22) consists of two identical chains, R31-R33 and R34-R36. The resistances of R31 and R36 are equal and two times greater than the other resistors. One chain is connected in the plate circuits of the left halves of the triggers and the other, in the plate circuits of the right halves of the triggers. The resistances of R31-R33 are much less than the plate loads of the triggers and so do not interfere with the operation of the triggers. The plate current in all the triggers can be considered the same. Thus the drop voltage across this chain of measuring resistors will be determined only by the combinations of trigger states, which depend on the number of counted pulses.

In the initial state of a counting decade the left triodes of all triggers are cut off and the voltage drop at the R31-R22-R33 chain is equal to zero. When the first pulse appears the first trigger trips; current flows through R33 and a voltage drop, V_1, which can be established by the meter, appears at it. When the second pulse appears the first trigger returns to its original state and the second trigger is tripped. The plate current of the left triode (it will be conducting) of the second trigger begins to flow through R32 and R33 and causes a voltage drop across them which is two times greater than the voltage drop across R33 when the first signal appeared (since two identical resistors are connected in series and therefore the total resistance of the chain is two times greater). When a third pulse arrives, the first trigger trips but the state of the second trigger is not changed (it will remain tripped). A voltage drop will appear across resistors R33 and R32 as a result of current flowing through the conducting left triodes of the first and second triggers. This voltage drop will be three times greater than the voltage drop created by the first trigger alone. This is because the current of the first and second triggers flows through R33. The voltage drop is

$$V = 2IR_{33} + IR_{32} = 2V_1 + V_1 = 3V_1$$

Thus with the appearance of every pulse the voltage across the resistor chain will change by different degrees. When the tenth pulse appears the circuit returns to its original state and the voltage falls to zero.

To obtain a decimal system of counting (a counting coefficient equal to 10) feedback pulses are fed from the output of a complete decade to the grids of tubes in the second and third cells.

The resistor chain R34-R35-R36 operates similarly. The only difference is that in the initial state the voltage across the chain is maximum. With the appearance of each pulse this voltage is decreased by 1/9-th part of the maximum value; with the appearance of the ninth pulse it becomes zero and the tenth pulse again increases it to its maximum value.

During the pulse count the voltage difference between the two chains is measured in steps: from maximum negative to maximum positive value in nine equal steps (Fig. 9.23). This voltage is measured by a control instrument whose scale is divided into ten parts and numbered left to right from zero to nine. In the initial state of the counting decade the needle of the instrument is at the extreme left position at zero and moves forward one division with the appearance of each pulse, indicating the number of pulses counted.

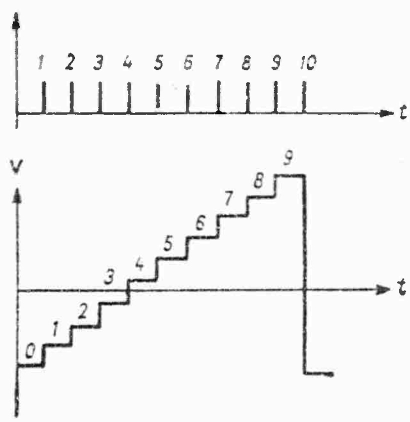

Fig. 9.23. Voltage curves of complete decades as indicated by meters

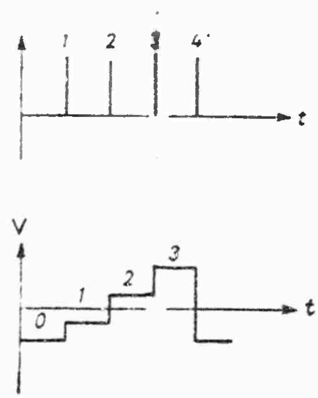

Fig. 9.24. Voltage curves of the incomplete decade as indicated by a meter

Such instruments are connected to the chain of measuring resistors in the second (tens) decade and the third (hundreds) decade.

The last (incomplete) decade (thousands) consists of only two trigger cells and can have only four different stable states.

Voltage curves at the terminals of the "Thousands" instrument are shown in Fig. 9.24. The scale of the instrument is divided into four segments.

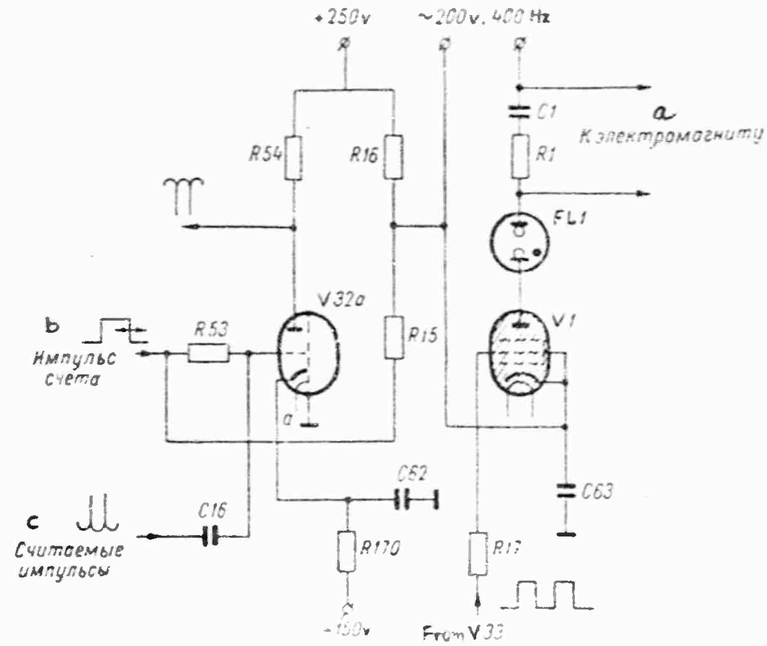

Fig. 9.25. Circuit of the selector and the thyratron stage

Key: a. To electromagnet
b. Count pulse
c. Pulses to be counted

The pulses for controlling the type-setting electromagnets, which are located in the MT-60, of the mechanism for printing the meteorological data are formed by the thyratron stages (Fig. 9.25). These stages are the transmitting link between the counting-decade trigger cells and the type-setting mechanisms. The grids of the thyratrons are connected to the plate loads of the right halves of the counting-decade trigger tubes. Four thyratrons are thus associated with each complete decade, and two are associated with the incomplete decade.

A 220-v., 400-Hz voltage feeds the thyratrons. The voltage source delivers +250 v. through R16 to the cathode. For reliable cut-off of the thyratrons during the pulse count by the counter a positive count pulse is fed through R15 to the cathode of the thyratron, resulting in an increase in the voltage at the cathode to 175 v. During the counting the voltage on the plates of the trigger in the counting circuit and, consequently, at the first grid of the thyratron, changes in jumps. However, the cathode potential (positive) remains above the potential of the grid, and the thyratron cannot be triggered. The voltage on

the plates of the conducting halves of the trigger tubes is less than that on the plates of the cut-off tubes. This voltage is applied to the first grids of the thyratrons.

After the count pulse ends the potential at the cathode of the thyratrons decreases and the thyratrons, connected to the cut-off trigger cells, fire. Thus a positive pulse delivered to the cathodes of the thyratron blocks the type-setting mechanism during the count time and prevents the electromagnets from operating until the count time has completely ended.

Each number of pulses to be counted delivered to the decade is associated with a combination of stable states of the triggers and, consequently, a specific combination of conducting and cut-off thyra-thyratrons.

The type-setting mechanism for printing meteorological data is arranged so that if only the first thyratron fires the number 1 is selected. If only the second thyratron fires the number 2 is selected. If only the third thyratron fires the number 4 is selected, etc. Thus, if, for example, seven pulses appear at the decade the combination of cut-off triggers and the correspondingly conducting thyratrons will be such that three thyratrons will fire. In this case the type-setting mechanism will select the number equal to 1 + 2 + 4, or 7. All the numbers from 0 to 9 are similarly selected in the decades governing tens and hundreds.

The count of thousands differs in that only two thyratrons are used for controlling the type-setting electromagnets. The firing of the first thyratron corresponds to the printing of 1. The firing of the second thyratron corresponds to the printing of 2. Both thyratrons firing gives the number 3. This is the maximum number of thousands that the counter can count.

Filament lamps (FL) are connected in the plate circuits of the thyratrons. In a cold state the resistance of the filament is small and at the moment the thyratrons fire the size of the initial current flowing through the coil of the electromagnets is significantly greater than the current rating. This is provided by the continued operation of the electromagnets after the count pulse has stopped. As the tube heats up its resistance increases and the current in the winding of the electromagnet decreases.

<u>The electronic count-pulse indicator</u>. The count-pulse indicator is designed to check the operation of the count system. In this unit, moreover, a 25-Hz voltage is developed (by dividing the 5000-Hz voltage) to supply the motor of the electric counter which records the radiosonde flight time. The indicator allows the correct selection of the voltage level at which the threshhold device in the receiving

system operates, since the pulses appearing at the counter can be seen on the screen of the tube at the moment of the count.

The electrical circuit of the indicator is similar to the circuits of standard oscillographic indicators and is not considered here.

The frequency divider circuit is assembled using three blocking oscillators and one trigger stage. The input of the circuit is fed 5000-Hz pulses, and rectangular symmetrical 25-Hz pulses are obtained at the output, which are fed to the recorder unit.

From part of the load of the cathode follower of the first divider a 1000-Hz voltage goes to the receiving system for controlling the operation of the count system.

9.5. The MT-50 Range Measuring System

The range measuring system is designed to handle the following operations: synchronize operation of the transmitter and the range indicator; select and observe the target on the range indicator; manual and automatic range tracking; measure range and continuously transmit data to the recording system; form the ultranarrow gating and blanking pulses which control the operation of the receiving system; create a voltage with a stabilized frequency of 5000 Hz for synchronizing the operation of the count system.

The object being tracked is selected and observed on the screen of the range indicator, which is assembled in an 8L029I cathode ray tube.

Two sweep scales are provided in the indicator for increasing the resolving power and precision of the bearing: coarse (30 km.) and fine (2 km.). Both sweeps are strictly interconnected in time. The circuit is arranged so that the fine sweep is always in the center of the 30-km. sweep and is set apart from it in the form of a "pedestal" by shifting the line of the coarse sweep up by two or three millimeters.

Turning the handwheel of the range mechanism effects a smooth delay of the beginning of the sweep for examining the target pulse on the range indicator screen from 0 to 150 km.

When a bearing is taken the answering or reflected signal is always in the center of the sweep line and should always be positioned symmetrically between the two electric hairlines. The hairlines are two dark marks (breaks in the sweep line) for which the pulses are formed in a channel for precise range determination.

The 2-km. sweep alone may be obtained on the c.r.t. indicator. In this case the entire length of the sweep line on the screen will correspond to a range of 2 km.

The range of the object being tracked is determined from the scales of the range mechanism, and an electric signal proportional to the range is fed into the recording system.

The range measuring system is made up of three units: a range unit, an automatic range tracking unit, and a range control unit.

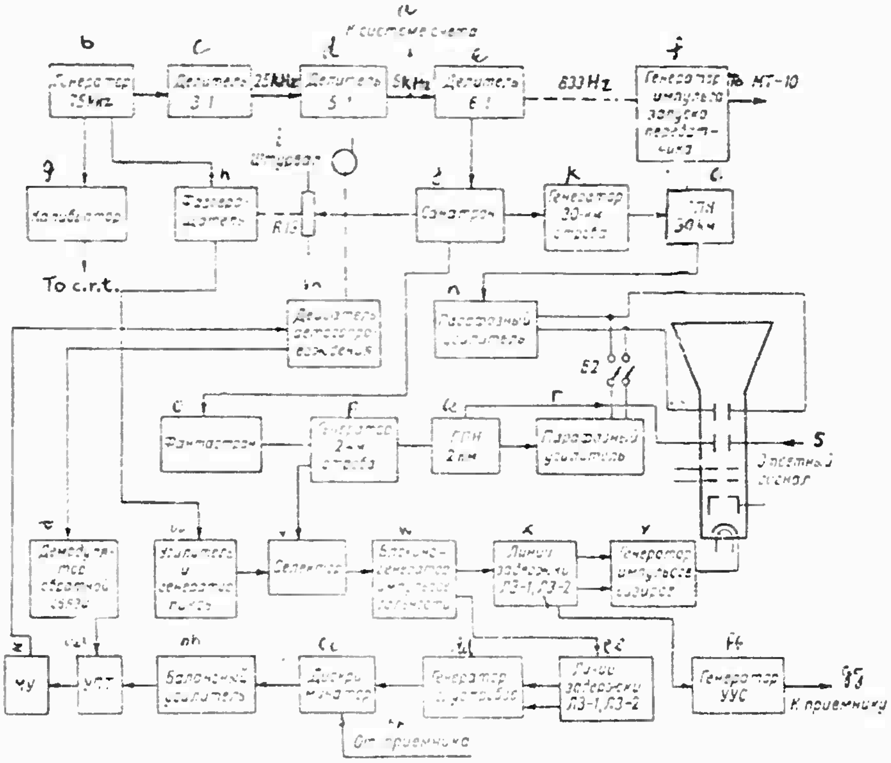

Fig. 9.26. Block diagram of the range measuring system

Key: a. To counting system
b. 75-kHz oscillator
c. 3:1 divider
d. 5:1 divider
e. 6:1 divider
f. Transmitter trigger-pulse generator
g. Calibrator
h. Phase shifter
i. Handwheel
j. Sanatron
k. 30-km. gate generator
l. 30-km. sawtooth-voltage generator
m. Autotracking motor
n. Paraphase amplifier
o. Phantastron
p. 2-km. gate generator
q. 2-km. sawtooth-voltage generator
r. Paraphase amplifier

[Key continued on following page]

s. Answering signal
t. Feedback demodulator
u. Gate generator and amplifier
v. Selector
w. Range-pulse blocking oscillator
x. Delay lines; DL-1, DL-2
y. Hairline-pulse generator
z. MA
aa. D.C. amp.
bb. Balance amplifier
cc. Discriminator
dd. Half-gate generator
ee. Delay lines; DL-1, DL-2
ff. UNG generator
gg. To receiver
hh. From receiver

The <u>range unit</u> develops a sinusoidal voltage of 75 kHz, transmitter trigger pulses, voltage for the 30-km. and 2-km. sweeps, pulses for synchronizing the count system, and pulses for triggering the blanking-pulse oscillator. The unit contains a calibrator and a cathode ray tube, which is the range indicator.

The <u>automatic range tracking unit</u> isolates the range-error signal voltage and converts it to a voltage that controls the servomotor. The unit also forms the pulses for the electric hairline and the ultranarrow gate (UNG).

The <u>range control unit</u> is designed for range tracking, determining the slant range from scales, and transmitting its running value to the recorder unit. A simplified block diagram of the range system is shown in Fig. 9.26.

The range system consists of several channels that fulfill specific functions: a transmitter triggering channel, a coarse range-measuring channel, a fine range-measuring channel, an automatic range tracking channel, and a calibrator circuit.

Since the elements of one channel can be located in different units, it is more convenient to consider the operating principles of a system in terms of the individual functional channels.

The <u>transmitter trigger channel</u>. A highly stable crystal-controlled oscillator is the master element synchronizing the operation of the transmitter, indicator, receiver, and counting system. The frequency of its sinusoidal oscillations is 75 kHz, which corresponds to the passage of the signal to an object (there and back) at a distance of 2 kilometers. The high stability of the crystal oscillator allows the range of the tracked object to be measured with great precision.

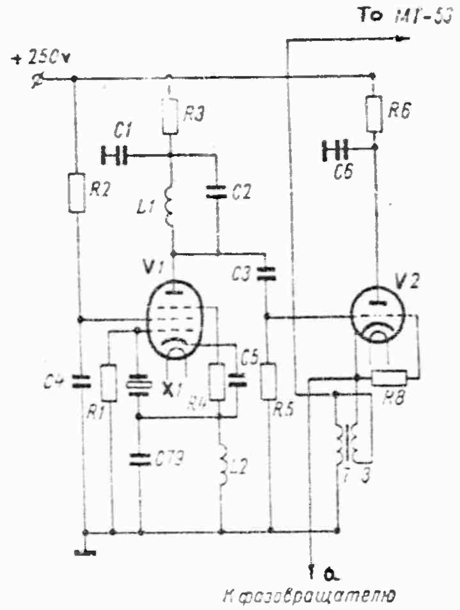

Fig. 9.27. Basic circuit of the crystal oscillator and the cathode follower

Key: a. To phase shifter

The crystal oscillator is installed at V1 in a circuit with electronic coupling (Fig. 9.27). This circuit functions as a self-exciting oscillator and sinusoidal voltage amplifier. A crystal, X1, is in the control-grid circuit of the oscillator and functions as a highly stable oscillation circuit with a natural frequency of 74,955 Hz. The high stability is due to the low heat expansion coefficient of the quartz plate, which provides a constancy of its mechanical dimensions despite temperature variations in the surrounding environment.

The screen grid of the tube functions as the plate in this circuit. The feedback voltage is taken from L2.

The L1C2 oscillation circuit is tuned to 75 kHz. It is the plate load of the stage and is used to strengthen the signal.

To increase frequency stability the oscillator is coupled to the load through a cathode follower (V2) with a transformer, T3, in the cathode circuit. The 75-kHz signal goes from T3 to the frequency dividers, the fine range-measuring channel, and to the calibrator circuit. From the output of the first frequency divider 25-kHz pulses are fed through the cathode follower to the second divider, which lowers their frequency to 5 kHz. The 5-kHz pulses go to synchronize

the count system and to the input of the third divider, at whose output pulses with a frequency of 833 Hz appear. Thus the division coefficients of the dividers are equal to 3, 5, and 6, respectively. This sequence of frequency dividing is necessary to obtain pulses with repetition frequencies of 5 kHz and 833 Hz.

The 833-Hz pulses (from the output of the third divider) are the sounding pulses of the station; they are fed to the transmitter trigger channel and to the coarse range-measuring channel.

The transmitter trigger channel consists of a trigger oscillator, two flip-flop multivibrators, a selector, and a final blocking oscillator.

The trigger oscillator is designed to prevent triggering of the transmitter during the time in which the radiosonde pulses are being counted. The other stages of the transmitter trigger channel form a 0.3-μsec. pulse with a 120-μsec. delay relative to the trigger pulse of the coarse range-measuring circuit. This transmitter trigger circuit allows signals from objects at ranges from 0 to 150 km. to be observed in the center of the sweep of the indicator and also cuts out the initial nonlinear section of the sweep delay circuit.

Positive transmitter trigger pulses with an amplitude of 65 v. and a repetition frequency of 833 Hz are taken from the cathode load of the trigger-pulse blocking oscillator and fed to the submodulator of the transmitter.

<u>The coarse range-measuring channel</u>. The coarse (30-km.) and fine (2-km.) sweep voltages are developed in the coarse range-measuring channel. These voltages are fed to the range indicator and create a sweep line on the c.r.t. screen.

Positive 833-Hz pulses go from the output of the third divider to the sanatron circuit. The sanatron (Fig. 9.28) is designed for smooth and linear delay of the sweep triggering with respect to the transmitter trigger pulse. The amount of delay depends on the size of the control voltage taken from the gate delay potentiometer, whose slider is kinematically connected to the handwheel and the motor of the range mechanism.

In the absence of trigger pulses the voltage on the plate of the left half of V11 is 55 v. The voltage on the third grid of V13, -40 v., is taken from the R52-R59-R60 divider. V13 is blocked at the third grid, and the voltage on its plate is fixed by the right half of the diode, V14, at a level of +220 v. The voltage on the control grid of V13 is close to zero. In this case all the cathode current is closed through the screen-grid circuit and, because of the screen current, the voltage at it falls to +30 v.

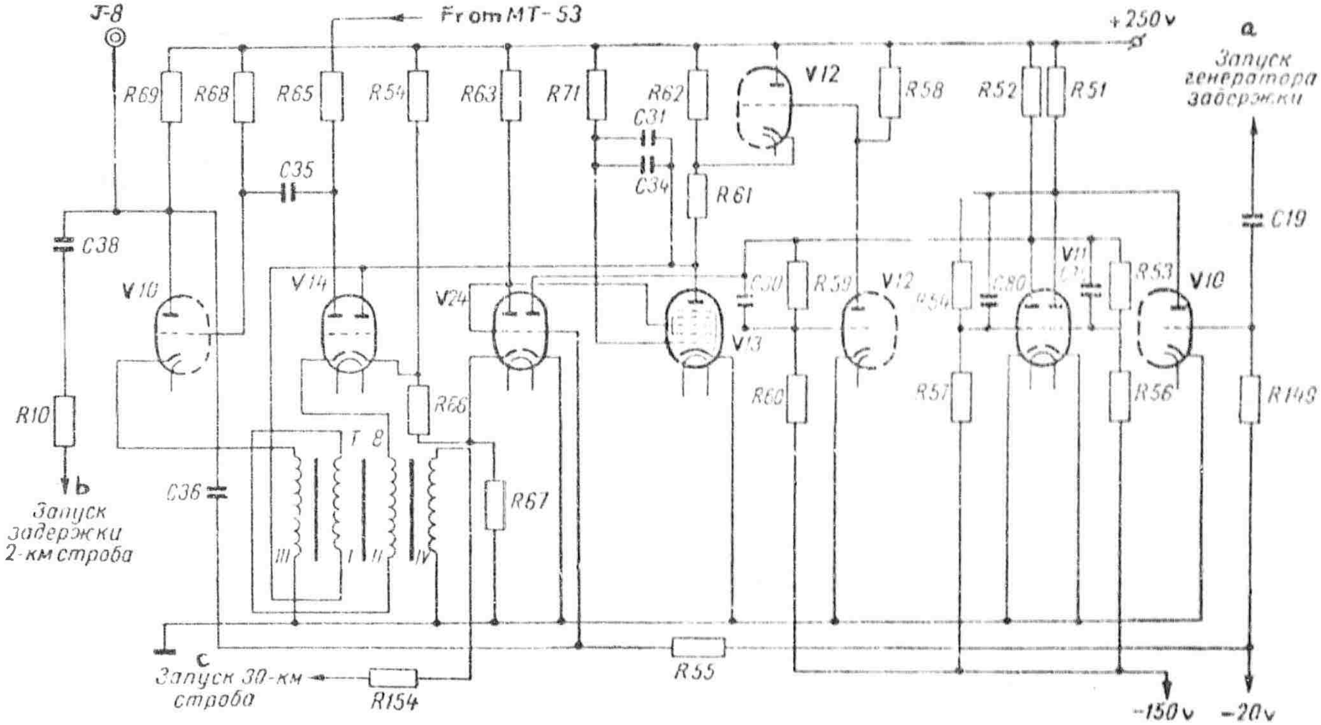

Fig. 9.28. The sanatron circuit

[Key on following page]

Key: a. Delay generator trigger
b. 2-km. gate delay trigger
c. 30-km. gate trigger

The left half of V12 is cut off, since its grid is connected to the third grid of V13, which has a potential of -40 v. The right half of V12 conducts and its current flows through the circuit consisting of R61, limiting diode V14, R66, and R67 to ground. A positive trigger pulse coming from the third divider through C19 causes the switching circuit to go into the second stable state. The switching circuit includes V24, V10, and V11. The left half of V11 is cut off. In this case the voltage on its plate increases to 220 v., which ought to lead to increased voltage at the third grid of V13. There is, however, no increase, since the potential at the third grid of V13 is limited by the grid current of the left half of V12 and is almost zero. The left half of V12 conducts almost completely, and the potential at its plate and, consequently, at the grid of the right half of V12, falls to 30 v. The right half of V12 cuts off and remains so during the entire working cycle, since the voltage at its cathode cannot fall below 40 v.

V13 unblocks at the third grid, and its plate voltage drops sharply. This sharp drop is fed through the plate-grid capacitors C31 and C34 to the first grid, lowers its potential, and prevents any further increase in plate current. In this case V13 is cut off almost completely at the first grid. The screen-grid potential increases to 120 v. and is limited by the left half of V24. This concludes the first operation cycle of the sanatron.

The second cycle is characterized by an increase in voltage at the control grid because of the discharge of C31 and C34 through R71 during the linear voltage fall-off at the plate of V13. Because of the stabilization of the charge current in the plate-grid capacitors C31 and C34 (owing to the positive plate-control grid feedback in V13), the changes in voltage obtain a high degree of linearity. The linearly dropping voltage goes from the plate of V13 through windings I and II of T8 to the cathode of the comparing diode (the left half of V14).

The plate of the diode is supplied with a control voltage from the gate delay potentiometer located in the range control unit (MT-[illegible]). At the instant the linearly falling and the control voltages are equal the diode unblocks, and the plate of V13 is connected to the grid of the cut-off tube (the left half of V10). The third stage of the operation of the sanatron circuit begins at this point, which is an avalanche-like process and the return of the circuit to its initial state.

The left half of V10 is unblocked in the initial state. At the moment the voltages are equal the potential at its grid decreases, resulting in a decrease in the voltage at its cathode. This voltage

increases in amplitude and is taken as a negative voltage from winding II of T8. Thus a positive feedback circuit is completed through the transformer.

The process is like an avalanche and ends with complete blocking of the left half of V10. A positive voltage pulse with a steep slope and an amplitude on the order of 100 v. is formed at the plate of the tube. This pulse goes to the grid of the cut-off right half of V24 and returns the circuit to its initial state: V13 is cut off at the third grid, with the result that the left half of V12 is cut off and the right half conducts. Immediately C31 and C34 begin to recharge through the right half ov V12, resistor R61, and the grid-cathode section of V13. The voltage at the plate of V13 increases sharply, the left half of diode V14 cuts off, and the current through winding II of T8 stops, resulting in a sharp increase in the potential at the grid of the cut-off tube (the left half of V10). As a result of this a positive cut-off pulse is formed at the plate of this tube. The duration of the linear voltage fall-off at the plate of V13 determines the time at which the cut-off pulse arises in the plate and cathode circuits of the left half of V10. The duration of this linear fall-off is in turn regulated by the voltage variation at the plate of the diode (the left half of V14), which falls between 220 and 45 volts. The voltage at the plate of the diode is fed from the midpoint of the gate delay potentiometer, R19 (Fig. 9.26), which is located in the range control unit and is kinematically connected to the range mechanism.

When the range handwheel is turned clockwise, the voltage on the plate of the left half of diode V14 is decreased, resulting in an increase in the duration of the linear voltage fall-off at the plate of V13. This varies the time that the cut-off-tube pulse appears. The cut-off-tube pulse triggers the 30-km. gate generator (coarse sweep) and the 14-km. gate generator (the phantastron).

The parameters of the circuit are selected so that the duration of the linear voltage fall-off at the plate of V13 and, consequently, the time when the cut-off pulse arises, can be regulated by varying the voltage on the plate of the left half of V14 between approximately 3 and 1040 microseconds, which covers the required 150-km. distance range.

The negative 833-Hz pulse from winding IV of T8 triggers the 30-km. gate generator, and the cut-off pulse goes from the plate of the left half of V10 to the 14-km. gate generator.

A sawtooth generator and the 30-km. gate generator form the 30-km. sweep. The 30-km. gate generator is assembled in a 6N1P as a flip-flop multivibrator. When the delay pulse from the sanatron appears, the multivibrator develops a 200-µsec. pulse, which corresponds to 30 km. A potentiometer labeled "30-km. Gate" is used to vary the duration of the 30-km. gate.

A negative pulse is fed from the mutlivibrator through the contacts of the scale relay (the sweep switch is in the 30-km. position) to the sweep generator, which is an oscillator that produces linearly increasing voltage.

The amplitude of the sweep voltage is controlled by the "Sweep Ampl." potentiometer.

Sawtooth waves with an amplitude of about 200 volts are fed from the sweep generator through the paraphase amplifier to the horizontal deflection plates of the tube.

A positive rectangular pulse is fed from the 30-km. gate generator to the c.r.t. modulator for dimming the retrance.

When the 2-km. sweep is formed a positive cut-off pulse goes from the output of the sanatron to the 14-km.-delay-pulse generator. The generator is assembled as a phantastron with cathode coupling. The delay phantastron develops negative 93-µsec. pulses, which corresponds to 14 km. in range. The duration of the 14-km.-delay pulses can be varied by the "Delay 14 km." potentiometer.

The trailing edge of the 14-km. pulse triggers the 2-km. gate generator, which is assembled as a flip-flop multivibrator with cathode coupling. The generator develops pulses with a duration of 13.3 µsec., which corresponds to 2 km. in range. The duration of the 2-km. gate is regulated by the "2-km. Gate" potentiometer. The positive pulse goes through a buffer stage to the sweep generator. From the sweep generator sawtooth waves are fed to one of the horizontal deflection plates of the c.r.t. and through the paraphase amplifier to the other horizontal deflection plate of the indicator.

A positive pulse from the 2-km. gate generator fed to the tube modulator dims the retrace.

At the 30-km. sweep (switch B2 is in the "Operate" position) one of the vertical deflection plates is fed by the 2-km. gate, which forms a pedestal at the coarse sweep, which is the coarse hairline. It indicates the time position of the fine sweep on the coarse sweep line.

Since the 2-km. gate is delayed by 14 km. relative to the beginning of the 30-km. sweep, it is in the middle of this sweep (Fig. 9.29).

The answering (reflected) signal from the output of the receiver goes through a single-stage amplifier and to the second vertical deflection plate of the tube. If the appearance of the answering signal coincides in time with the appearance of the 2-km. gate, a burst appears on the pedestal, which serves to precisely determine the range.

The positive 2-km. gate is fed to the automatic range-tracking unit (to the selector) to form the ultranarrow gate, the electric hairline, and the half-gate [polustrob] pulses for automatic range tracking.

<u>The fine range-measuring channel</u>. This channel provides for finding the range to the target with a precision no less than 10 m.

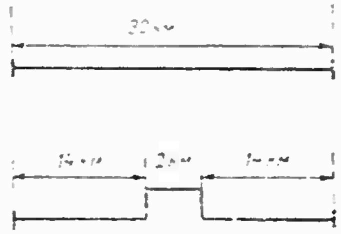

Fig. 9.29. The position of the 2-km. gate on the 30-km. sweep

The distance is read off the scales of the range mechanism when the answering signal is symmetrically positioned relative to the pulses of the electric hairline. The electric hairlines are formed by the chain of stages in the channel for precise determination of range.

The 75-kHz voltage generated by the crystal oscillator goes through the cathode follower to the phase splitting bridge consisting of R1, R2, R3, R4, R5, C1, and C6 (Fig. 9.30). Four sinusoidal voltages 90° apart are taken from the bridge. Their amplitudes are equalized at the input of the bridge by resetting the slider of potentiometer R1, "Balance." Variable resistors R2, "Phase -90°," and R5, "Phase +90°," are used to equalize the effective resistance and capacitance.

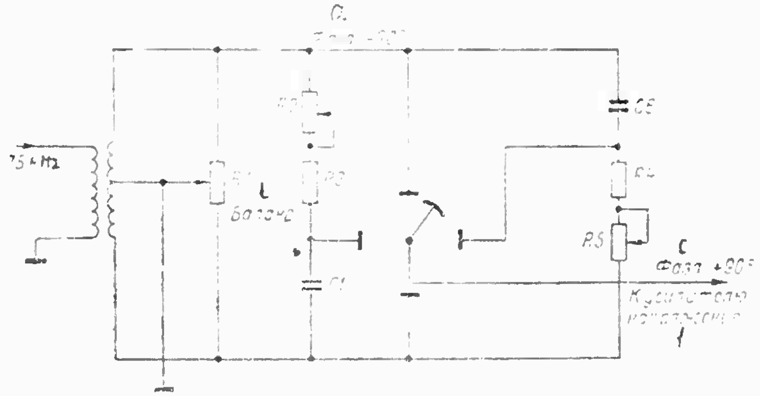

Fig. 9.30. Circuit of the phase splitter

Key: a. Phase -90° c. Phase +90°
b. Balance d. To voltage amp.

A capacitive-type phase shifter is connected at the diagonal of the bridge. It consists of four plate segments and one unbroken plate, between which a blade made of a specially formed dielectric rotates. As the blade rotates, the capacitance of each section is smoothly varied. A voltage whose phase varies linearly from 0 to 360° as the rotor turns is taken from the output of the phase shifter. A specific phase displacement of the output voltage corresponds to a specific angle of rotation of the rotor. The rotor of the phase shifter is kinematically connected to the handwheel and motor of the range mechanism.

The phase shifter output voltage is used in the end for developing the ultranarrow gate, the half-gates, and the electric hairline for precise range, and hence a shift in the phase of this voltage by any angle produces a proportional shift of these pulses in time.

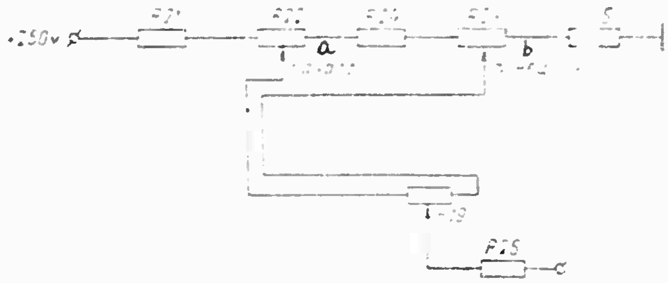

Fig. 9.31. Circuit showing the connection of the gate delay potentiometer

Key: a. Beginning
b. End

The 75-kHz voltage is fed from the output of the phase shifter to the two-stage voltage amplifier, and then to the peak generator.

As the rotor of the phase shifter turns, the slider of the gate delay potentiometer, R19, moves (cf. Fig. 9.26) (this potentiometer is located together with the phase shifter in the range control unit). The voltage at the potentiometer is supplied from the divider consisting of R21, R22, R23, R24, and R25 (Fig. 9.31).

When the range scale is set at 0 and 150 km., the delay of the 30-km. and 2-km. gates is governed by potentiometers R22, "Beginning," and R23, "End," respectively.

From the peak generator sharp positive and negative 75-kHz pulses are fed to the range-pulse selector in the autotracking unit. The 2-km. gate from the range unit is also fed here. When the gate and the peak coincide in time, the selector develops a negative pulse which triggers the blocking oscillator. The blocking oscillator

develops positive 833-Hz range pulses whose delay relative to the transmitter trigger pulse can be smoothly varied from 0 to 150 km. by varying the control voltage on the sanatron, which is taken from the slider of R19 in the range mechanism.

The range pulses go through the DL-1 and DL-2 delay lines (cf. Fig. 9.26) to the starting tube and trigger the hairline pulse generator (Fig. 9.32).

Since each range pulse is fed to the starting tube, V25, from two different points in the delay line, two pulses appear at its output which are out of phase with each other. These pulses trigger the hairline generator, V3, which develops two 0.3-µsec. positive pulses 1.2 µsec. apart; the pulse repetition frequency is 833 Hz.

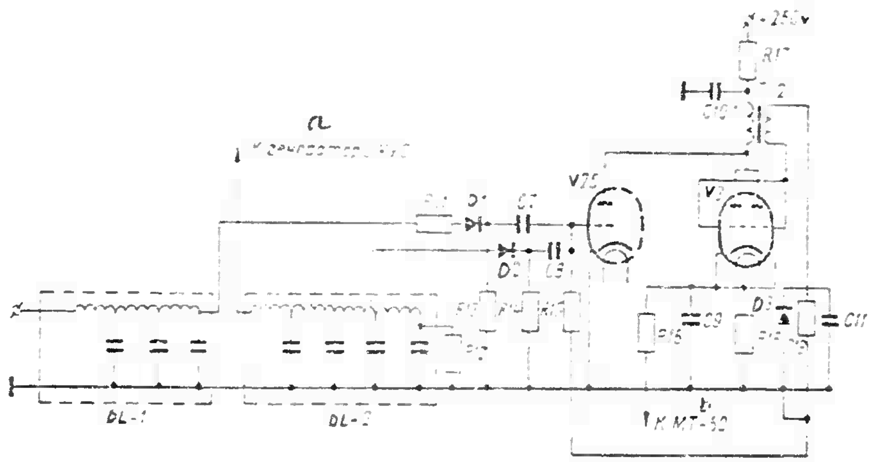

Fig. 9.32. Circuit of the delay lines and the hairline pulse generator

Key: a. To UNG generator
b. To MT-50

These pulses go to the cathode of the c.r.t. and form an electric hairline on the 2-km. sweep line in the form of two dark marks (breaks in the sweep line).

Rotation of the phase shifter rotor is used to achieve symmetrical positioning of the answering signal relative to the dark marks and precise determination of the range of the object from the scales.

The pulse used to trigger the UNG generator is taken from a tap on DL-2 (cf. Fig. 9.26); this generator is assembled as a blocking oscillator with parallel triggering. The pulse from the UNG at an amplitude of 120 v. and a duration of 0.5 usec. is taken from the winding of the pulse transformer and fed to the main amplifier unit of the receiving system for the purpose of gating the automatic angle-control channel in the corner-reflector mode.

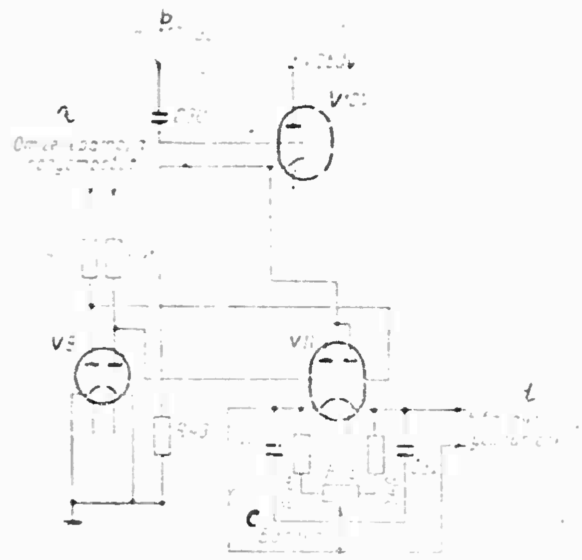

Fig. 9.33. Discriminator circuit

Key: a. From half-gate generator
b. From MT-30
c. Balance I
d. To balance amp.

The UNG pulse delay is adjusted so that it falls between the dark marks, i.e., the time it appears corresponds to the time the answering signal appears.

<u>The automatic range tracking channel</u>. The autotracking channel functions as a tracking system that automatically rotates the range mechanism when the distance to the target changes. At the root of the principle of autotracking is a certain circuit for isolating an error signal as the time position of the answering-signal changes relative to the half-gate reference pulses. The range pulse is fed from five different sections of DL-1 and DL-2 to the contacts of switch B1, which shifts the half-gates by 1.0-1.6 µsec. relative to the dark marks. The phases must be shifted because in the "Radiosonde" mode the automatic range tracking does not use the burst of the answering signal but the pause that follows the burst.

The half-gate generator is assembled in three tubes in a blocking oscillator circuit with parallel triggering and forced cut-off. Pulses from the output of the half-gate generator are fed to the discriminator.

An error signal proportional to the deviation in the time position of the answering-signal pulse relative to the gate interface is isolated in the discriminator stage, whose circuit diagram is shown in Fig. 9.33.

The half-gate pulses are fed through V9 to the grids of the discriminator tubes. In the absence of these pulses the tubes are cut off at the control grids by approximately -90 volts.

The reflected signal of the answering pause of the radiosonde is fed from the main amplifier unit through C30 and the cathode follower, V10b, to the plates of the discriminator, V11. Approximately -100 v. is delivered to the cathodes of this tube through R45, "Balance I."

In the absence of a reflected signal, current flows in the tubes when the half-gate is operating; it charges C32 and C31 to an equal potential, whose magnitude depends on the noise level of the receiver. Noise voltage affects the plates of the discriminator constantly.

The discriminator is balanced when there is no signal by means of potentiometer R45, "Balance I," i.e., the potentials at the cathodes of both halves of the tubes are adjusted to be equal.

When a reflected signal is delivered to the plate which corresponds in time with the half-gate, the potentials at the cathodes can be equal only if the center of the reflected signal is at the junction of the half-gates. In this case both halves of V11 pass equal currents and C31 and C32 charge to the same potential.

If the signal is asymmetrically positioned relative to the junction of the half-gate pulses, different currents pass through the tubes (the potentials at the cathodes of both halves of a tube will not be the same) and the condensers charge to different potentials. The resul is that an error signal (a constant voltage) will be developed in the circuit; the polarity of this signal is determined by the placement of the center of the reflected signal (lagging or leading) relative to the junction of the half-gate pulses. The magnitude of the error signal is determined by the magnitude of the time discrepancy between the center of the reflected signal and the junction of the half-gates and is proportional to the difference in the voltages on C31 and C32.

Constant voltages are fed from the cathodes of the discriminator tubes to the grids of the tubes in the balance amplifier (cf. Fig. 9.26). Besides amplifying, the balance amplifier converts the error signal to a voltage of either polarity. This two-polarity error signal is necessary in order to turn the autotracking motor in one direction or the other, depending on the deviation of the answering signal relative to the junction of the half-gates.

The balance amplifier allows subtraction of the voltages delivered to it from C31 and C32.

With a symmetrical placement of the answering signal relative to the junction of the half-gate pulses, the error signal is zero.

The error-signal voltage goes from the output of the balance amplifier to the RC low-pass filter. When the high-frequency components of the signal, which could result in damaging overloads of following stages, pass through the filter they are filtered out and fed to the adder stage of the d.c. amplifier, which is also supplied with feedback voltage that stabilizes the operation of the tracking system. The feedback voltage is taken from the control winding of the autotracking motor. The amplitude of the voltage is proportional to the speed of rotation of the motor, and the phase is shifted by 180° when the direction of rotation is changed.

The feedback voltage goes to the feedback demodulator, which is a full-wave phase-sensitive detector. At the input of the demodulator a constant voltage appears whose polarity depends on the direction of rotation of the servomotor and whose amplitude is proportional to the speed of rotation of the motor.

Summation of the error-signal voltage and the feedback voltage, as well as preamplification of the summed signal, takes place in the first stage of the d.c. amplifier.

The second d.c. amplifier stage operates as a current amplifier. The control windings of the magnetic power amplifier (MA) is connected in the plate circuit of this stage.

The voltage taken from the output of the magnetic amplifier is used for controlling the servomotor voltage. It is fed to the control winding of the motor and makes it rotate so that the error signal decreases. The motor is mechanically connected to the rotor of the phase shifter and the slider of potentiometer R19. As the rotor of the phase shifter turns, the phase of the 75-kHz voltage is changed, so that the junction of the half-gate pulses is moved to the center of the reflected signal. When the reflected signal coincides with the junction, the error voltage disappears and the motor stops.

If the center of the reflected signal moves to the other side of the half-gate junction, the sign of the error signal changes and the motor turns the other way until the error voltage disappears. The tracking system thus automatically follows the change in range and records this change on the scales of the range mechanism.

The running values of the slant range are transmitted to the recording unit by the coarse and fine selsyn sensors located in the range control unit. Both selsyns are kinematically connected to the range mechanism, and their rotors turn proportional to the change in the recorded magnitude.

The <u>calibrator circuit</u> is designed for tuning and checking the linearity of tracking of the electric hairlines of the 2-km. sweep as the fine range scale is rotated. The calibrator consists of a

phase-shifting network and a frequency multiplier. To increase the calibration precision of the bridge of the phase shifter the 75-kHz signal is multiplied to 600 kHz in the calibrator circuit, which corresponds to the distance between the 250-m. calibration marks.

In the "Calibrate" mode the 600-kHz signal is fed at a level of 80 v. from the circuit of the last frequency multiplier through the switch that selects the mode of operation to one of the vertical deflection plates of the tube. This produces calibration marks on the sweep line which are used to determine the amount of shift of the dark marks (hairlines) and compare it with the indications of the range mechanism scale. The phase shifter is adjusted if the results differ. In other modes of operation the calibrator is switched off.

Curves of the main voltages in the range system are shown in Fig. 9.34.

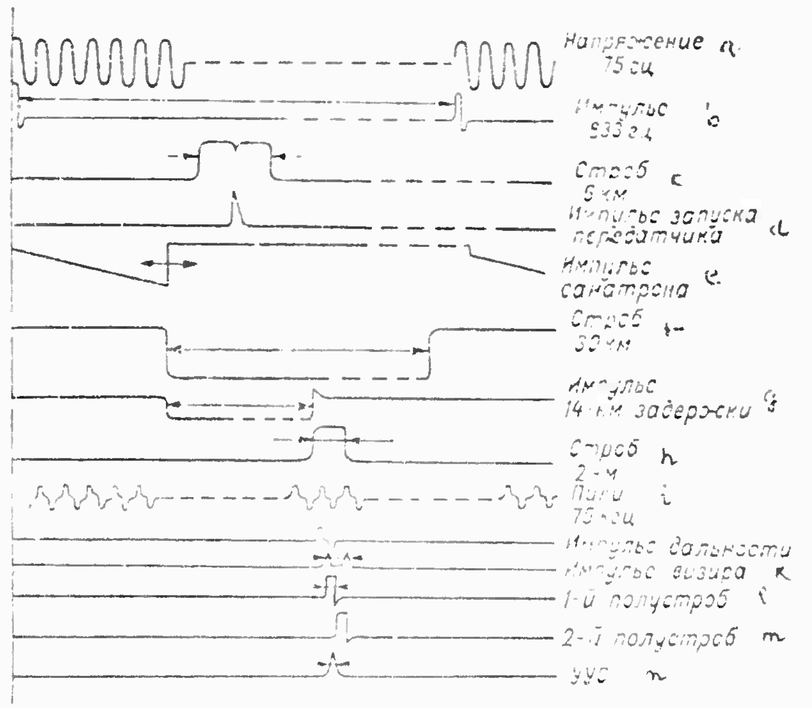

Fig. 9.34. Voltage curves in the MT-50 system

Key: a. 75-Hz voltage
b. 833-Hz pulse
c. 6-km. gate
d. Transmitter trigger pulse
e. Sanatron pulse
f. 30-km. gate
g. 14-km. delay pulse
h. 2-km. gate
i. 75-kHz peaks

[Key continued on following page]

j. Range pulse
k. Hairline pulse
l. First half-gate
m. Second half-gate
n. UNG

9.6. The MT-60 Data Transmission and Recording System

The system of transmitting and recording the data is designed for transmitting the running values of the azimuth, the angle of elevation, and the slant range of the tracked object to the automatic recording device and for recording on paper tape the running angle coordinates, the slant range, the flight time, and the radiosonde signals carrying the coded meteorological information.

The MT-60 contains three identical tracking systems (for azimuth, angle of elevation, and range) that are used to transmit the angle coordinates and the slant range to the recorder unit during manual or automatic tracking of an object. Each tracking system consists of a summing amplifier for the sensors, a servoamplifier, a magnetic amplifier, and a recorder. The system also includes selsyn sensors for fine and coarse reading of the azimuth and the angle of elevation, located in the antenna column, and selsyn range sensors, located in the range control unit of the MT-50, as well as servomotors for the recorder and coarse and fine selsyn transformers. Because the systems are all the same we shall consider only the azimuth system (Fig. 9.35).

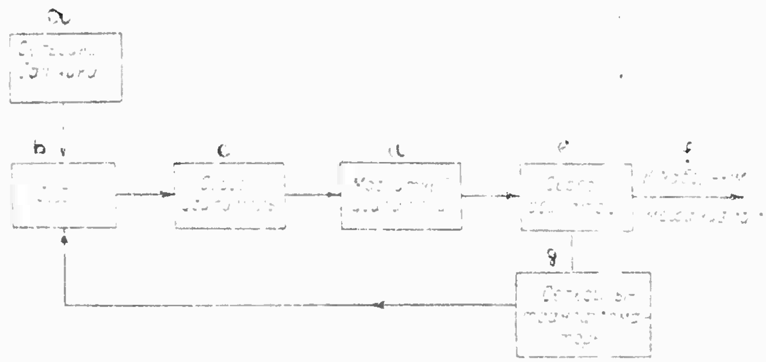

Fig. 9.35. Block diagram of the MT-60

Key: a. Selsyn sensors
b. Sensor summing amplifier
c. Servoamplifier
d. Magnetic amplifier
e. Servomotor
f. To printing mechanism
g. Selsyn transformers

The sensor summing amplifier. The signal from the selsyn sensors goes to the sensor summing amplifier (SSA), which is designed to sum the error signals delivered by the two coarse and fine selsyn transformers.

The summing circuit provides the requisite precision of transmission of the coordinates and prevents false synchronization from appearing in the system. An error signal appears if the positions of the rotors of the selsyn sensors and the selsyn transformers in the channel are not matched. The rotors of the selsyn sensors are connected to the rotation axes of the antenna along the azimuth and angle of elevation (during transmission of angle coordinates) and to the range mechanism in the range trasnmission channel. The rotors of the selsyn transformers are connected with the servomotors in the recorder unit.

From the output of the SSA the error signal goes to the servoamplifier.

The servoamplifier. The summed error signal is amplified in this stage and converted to a d.c. voltage that controls the magnetic amplifier. The servoamplifier is assembled as a balance circu. . in two twin triodes.

The d.c. control voltage goes from the output of the servoamplifier to the control windings of the magnetic amplifiers.

The magnetic amplifier is designed to amplify and convert the error signal to a voltage controlling the servomotor. The magnetic amplifier has two a.c. windings, two control windings, and one bias winding. The operation of the magnetic amplifiers is based on the change of the magnetic permeability of iron when magnetized by continuous current, which allows the inductance of the a.c. windings to be greatly changed by small changes in the control current.

The magnetic amplifier is fed 220 volts at 400 Hz.

Thus the magnetic amplifier converts the constant error-signal voltage to an amplified 400-Hz alternating voltage.

The control winding of the servomotor located in the recorder unit is the load for the magnetic amplifier.

The recorder servomotor is designed to exhaust the errors in the mismatch of the running coordinates and to transmit motion to the appropriate scales (azimuth, angle of elevation, and range) and to the type-setting printing mechanisms.

An error signal appears at the output of the summing amplifier when there is a mismatch in the angular position of the selsyn sensor rotors for a particular coordinate and the selsyn transformer rotors. This signal is amplified and converted by the servoamplifiers and the magnetic

amplifiers and fed to the control winding of the servomotor. The motor begins to rotate and turns the rotor of the selsyn transformer (cf. Fig. 9.35). When the angle positions of the rotors coincide, the error signal disappears and the servomotor stops. The tracking system will thus automatically exhaust the angle of rotation specified at each coordinate by the selsyn sensors.

The servomotor of the tracking system is connected to the type-setting mechanisms for printing range, azimuth, and elevation angles that compose the running values of the coordinates of the object being tracked and prepare them for printing on the paper tape.

The recorder is used to automatically record on paper tape the radiosonde signals (the meteorological data) appearing every five seconds and the running coordinates and time marks appearing every 30 seconds.

The recorder includes mechanisms for advancing the paper tape and the inking tape, mechanisms for the servomotors associated with the azimuth, the angle of elevation, and the range, type-setting mechanisms for printing the angle of elevation, azimuth, range, meteorological data, and time, a printer, a working-pulse unit, a circuit for regulating the count time, and instruments to indicate the results of the count.

The paper- and inking-tape drives are designed to pull the graph tape on which the running coordinates, radiosonde flight time, and meteorological data are recorded and the inking tape, which allows the composed data values to be recorded during the printing. The inking-tape drive has a reversible motor for changing direction and motion.

The typesetters for printing the angle of elevation, the azimuth, and the range are designed to compose the values of the running coordinates and print them on paper tape. They contain drum-type numbered dials with numbers in relief. Each typesetter is connected by a universal coupling with the corresponding servomotor. As the shaft of the servomotor rotates, the dials of the typesetters turn to the corresponding angle and set the necessary coordinate values and prepare them for printing.

The typesetter for printing the time has two electromagnets con nected to a wheel in the device which has plus (+) and minus (-) signs in relief on it. The minus sign corresponds to 00 sec.; the plus sign means that 30 seconds must be added to the printed time. The wheel is connected by a ratchet gear to the first dial drum. The typesetter for printing the time has three dial drums, for units, tens, and hundreds of minutes. A composed result can be reset by a reset knob brought out to the front panel of the recorder unit.

The typesetter for printing the meteorological data consists of rack differential gears for thousands, hundreds, tens, and units, which are designed for transforming the electric parameters of the results of the count into mechanical ones (the angles of rotation of the corresponding axes). These mechanisms have 14 electromagnets with moving cores. The windings of the electromagnets are connected in the plate circuits of the output stages of the electronic counter. Since the electronic counter has four counting decades, the electromagnets are also divided into four decades: the decades for units, tens, hundreds, and thousands. A shift of the cores of the electromagnets causes rotation of the dials of the typesetter for printing the meteorological data.

The printer of the recorder unit consists of six striking electromagnets, which print the time, the angle of elevation, the azimuth, the range, thousands, hundreds, tens, and units of the meteorological data. The first four electromagnets are controlled by the electronic time counter through printing stages in the working-pulse unit. The time counter is also located in the working-pulse unit; its main element is a synchronous motor, SM-2. Using groups of contacts which close as it turns, this motor controls the operation of the stages in the time typesetter as well as the operation of the stages for printing time, range, and angle coordinates.

The printing stages, assembled in thyratrons, develop pulses every 30 seconds which cause the striking electromagnets to trigger. When triggered, the striking electromagnets strike the printing bars, and they in turn strike the paper, pressing it through the inking tape to the numbers on the drums of the typesetter dials.

The radiosonde signals (the meteorological data) are recorded as follows. The electromagnets of the typesetter are controlled by voltages coming from the electronic pulse counter in the MT-40 system. After the radiosonde-pulse count is finished, the output thyratrons are switched on. The totals of the count will determine which thyratrons fire. The state of the thyratrons and, therefore, the position of the cores in the electromagnets (the thyratrons are connected in the electromagnet circuit), will correspond to the sum state of the counter.

The electromagnets transmit the sum of the count to the output shafts of the rack differential gears, which turn the dial drums to the correct angles. The print pulse that actuates the striking electromagnets follows 3 seconds after the thyratrons in the electronic counter fire. The coordinates and time are recorded once every 30 seconds.

9.7. The MT-70 Antenna Control System

The antenna control system is designed to control the movement of the antenna along the azimuth and the angle of elevation.

Three modes of operation of the antenna control system are provided in the station: an automatic tracking mode, used for precise determination of the angle coordinates and automatic tracking of the change in azimuth and the angle of elevation of the tracked object; a manual control mode, used for searching for the object and following it before switching to automatic tracking; an automatic sector scanning mode, used for searching for an object in a specific sector.

Push buttons labeled, "Manual," "Search," and "Automatic Control," located on the front panel of the antenna control unit, ard used to change from one mode of operation to another. The "Stop" button is used for rapidly stopping the antenna along both coordinates.

The following units are found in the antenna control system: an automatic angle-coordinate tracking unit, an azimuth and elevation-angle tracking unit, a unit containing the final magnetic power amplifiers, an antenna control unit, and an antenna column.

The automatic angle-coordinate tracking unit is designed to isolate the 24-Hz error-signal voltage from the video signals coming from the output of the main amplifier when a radiopilot is being tracked or to isolate the error-signal voltage from the super noises when a radiosonde is being tracked.

The automatic tracking unit includes an 300-kHz amplifier, a super-noise envelope detector, a peak video-signal envelope detector, a fast-acting automatic gain control (FAGC), a 24-Hz tuned amplifier, an amplifier for the alternating current in the azimuth and elevation-angle channels, auxiliary a.c. amplifiers, phase-sensitive rectifiers, and instruments to indicate the bearing error.

The azimuth and elevation-angle tracking unit is used to convert the error-signal voltage to a control voltage for the azimuth and elevation-angle channels. This unit operates in all modes of the station's operation.

The unit consists of two identical channels, one for the azimuth and one for the angle of elevation. In each channel there are phase-sensitive rectifiers for the error-signal and feedback voltages and two stages of d.c. amplification.

The final magnetic power amplifier unit is designed to amplify the control signal to a level sufficient for actuating the antenna rotation servomotors. The unit includes two identical power amplifiers, one for the azimuth and one for the angle of elevation.

The antenna control unit is designed for controlling the position of the antenna in space and switching the modes of operation of the system. The unit includes mechanisms for manual control of the antenna and the automatic sector search and the circuit for switching the modes of operation of the system.

The antenna column rotates the antenna along the azimuth and the angle of elevation, determines the angle coordinates of the target, and transmits them to the recording system. The antenna column consists of azimuth and elevation-angle actuators, azimuth and elevation-angle selsyn drives, a slip ring, and the control linkage for the reference voltage generator. The antenna column is set up on a poured foundation to which all major junctions and the parabolic reflector are attached.

Let us examine the operation of the MT-70 system under the various operating conditions of the antenna control.

Automatic tracking. Two modes of automatic tracking are provided in the station: automatic tracking of a radiopilot and automatic tracking of the RKZ-2 radiosonde. The need for two modes of operation was brought about by the difference in the signals from these objects at the input of the station. In the "Radiosonde" mode the signal is a super noise amplitude modulated at a frequency of 24 Hz. In the "Corner Reflector" mode the radiopilot signals reflected from the corner reflector are amplitude modulated by a frequency of 24 Hz. The operating principle of the tracking system using angle coordinates is identical in both modes.

The principle of the bi-signal zone is fundamental to the automatic tracking of a target. A bi-signal zone is created as a result of conical scanning. The axis of the lobe of the radiation pattern is offset from the geometric axis of the paraboloid by an angle of about 2° because of the asymmetric placement of slots in the lateral surface of the counter-reflector of the antenna head. The counter-reflector is rotated by a motor, with the result that the maximum of the lobe of the radiation pattern describes a circle in space, and the lateral surface describes a cone. The motor rotates at 24 r.p.s., and the frequency of the conical scanning of the radiation pattern is thus 24 Hz.

If the tracked object lies on the geometric axis of the antenna, its answering signals at the output of the receiving system will be identical in amplitude for all positions of the radiation pattern (Fig. 9.36a). If the tracked object moves relative to the axis of the paraboloid, the answering signals will be amplitude modulated, according to the sinusoidal principle, at a frequency of 24 Hz, which corresponds to the rotation speed of the radiation pattern. The phase of the modulation envelope depends on the direction of shift of the object relative to the axis of the antenna, and the depth of the modulation depends on the amount of the shift (Fig. 9.36).

The rotation of the reference-voltage generator is synchronized with the rotation of the radiation pattern; this generator develops two sinusoidal voltages which differ in phase by 90°.

The function of the autotracking channel is to compare the modulation curve with the reference voltages, to isolate the error signal, and to control the antenna rotator along both coordinates.

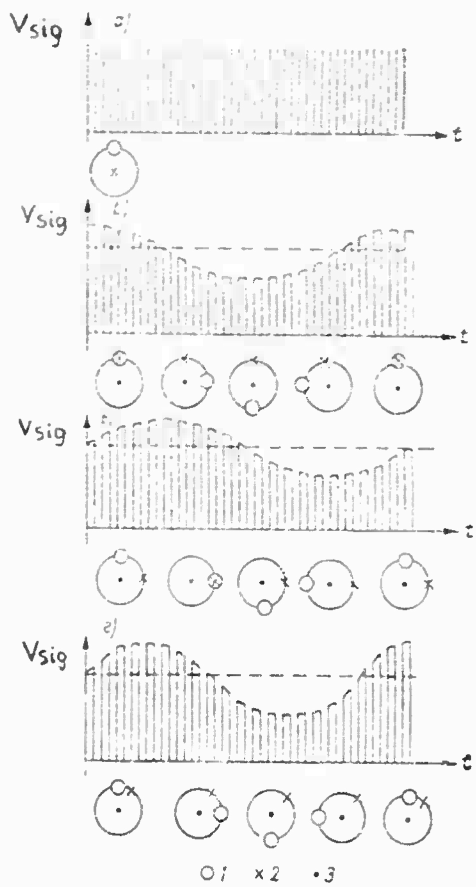

Fig. 9.36. Change in the phase of the envelope of the received signals
a) object on axis of antenna; b) object shifted up along elevation angle; c) object shifted right along azimuth; d) object shifted along azimuth and elevation angle; 1) beam axis; 2) object; 3) antenna axis

The block diagram of the automatic angle-coordinate tracking channel is shown in Fig. 9.37.

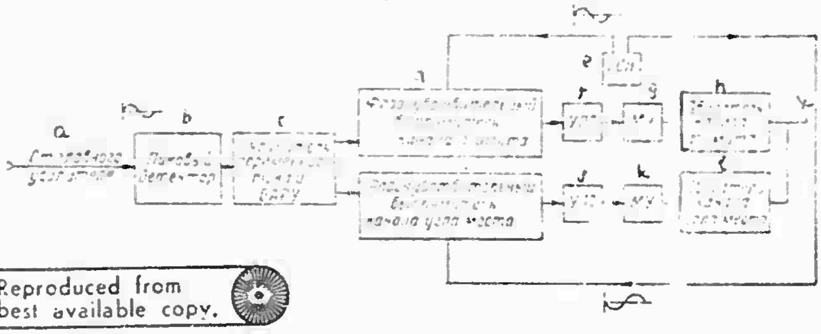

Fig. 9.37. Block diagram of the angle-coordinate automatic tracking channel

Key: a. From main amplifier
b. Peak detector
c. A.c. amp. and FAGC
d. Azimuth channel phase-sensitive rectifier
e. RVG
f. A.c. amp.
g. MA
h. Azimuth motor
i. Elevation-angle phase-sensitive rectifier
j. A.c. amp.
k. MA
l. Elevation-angle motor

From the output of the automatic radiosonde-angle control channel or the automatic corner-reflector angle control channel in the main amplifier unit of the receiving system the voltage is fed to the input of the automatic angle-coordinate tracking system of the MT-70.

When a radiopilot is being tracked the reflected signal is fed to the peak detector, where it is converted to a voltage whose variation corresponds to the form of the envelope of the reflected signal. The output voltage of the peak detector consists of a d.c, component proportional to the total level of input signals and an a.c. component with a frequency of 24 Hz, which corresponds to the scanning frequency of the electromagnetic beam. The d.c. component of the detected voltage is needed for the operation of the FAGC circuit in both modes.

Depending on the mode of the station's operation, the FAGC stage is supplied with either a signal from the output of the 800-kHz detector ("Radiosonde" mode) or a signal from the output of the peak detector ("Corner Reflector" mode). The amplitude of the 24-Hz voltage at the output of the FAGC stage is held constant despite the amplitude of the incoming signal (with a constant depth of modulation of the 24-Hz input voltage).

The FAGC stage is assembled in a 6K4P with a variable transconductance characteristic, thanks to which it can be used for the fast automatic gain control.

When the intensity of a signal increases, the d.c. component of the output voltage from the detector is increased and shifts the working point of the characteristic of the tube into a less steep region (Fig. 9.38). As a result the gain drops and the amplitude of the a.c. component at the output of the tube changes insignificantly.

With a decrease in signal intensity the d.c. component of the voltare at the output of the detector decreases, with the result that the working point of the characteristic is shifted into a steeper region. Amplification thus increases and the a.c. component, whose amplitude remains almost the same as before, is taken from this stage.

From the output of the FAGC stage (Fig. 9.37) the 24-Hz sinusoidal voltage is fed to phase-sensitive rectifiers that convert the a.c. signal voltage to d.c. signal voltage whose magnitude and polarity depends on the amplitude and phase of the signal at the input. The phase-sensitive rectifiers in the azimuth channel and the elevation-angle channel are identical, so we shall describe only the operation of the phase-sensitive rectifier in the azimuth channel.

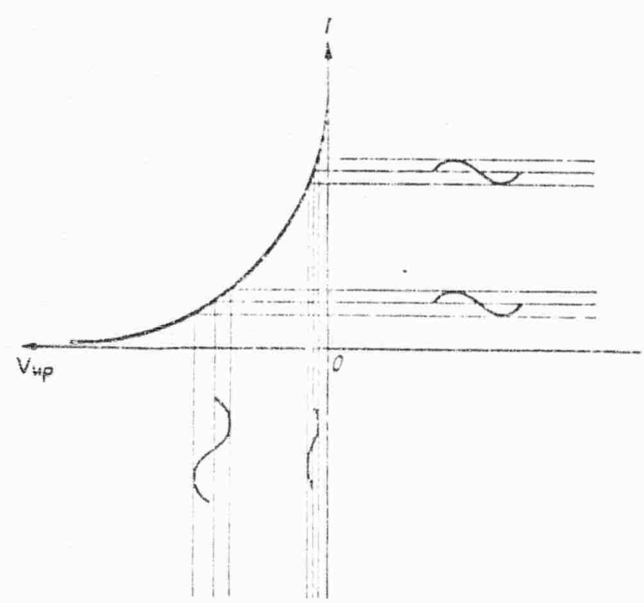

Fig. 9.38. Voltage curves explaining the operation of the FAGC

The circuit of the phase-sensitive rectifier (demodulator) is shown in Fig. 9.39. It is assembled in V1 and V2 (6Kh2P's) in a full-wave rectifier circuit. Resistors R1, R2, and R3 are the load.

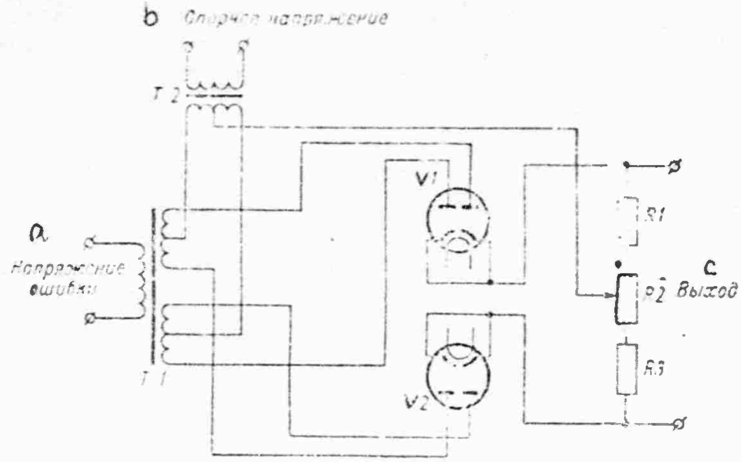

Fig. 9.39. Circuit of the phase-sensitive rectifier

Key: a. Error voltage
b. Reference voltage
c. Output

The error voltage is fed from T1 and the reference voltage from T2. The secondary windings of T1 are connected directly to the plates of V1 and V2. When the rectifier is operating the sum of the e.m.f. developed in the sections of T1 and T2 is applied to the electrodes of each diode through the corresponding shoulder of the load R1, R2, R3. The amplitude of the reference voltage from T2 is always selected to be greater than the error signal coming from T1, thus either the left halves or the right halves of V1 and V2 are conducting during each half-cycle of the reference voltage. Since the cathodes of V1 and V2 are connected at opposite shoulders of the symmetrical load, the voltage taken from the load will depend on the ratio of the amplitudes of the voltages applied to the simultaneously conducting diodes.

When there is no error-signal voltage the current through each half of the load is equal but moving in the opposite direction. Since the load resistance in each half is equal, the potential at the load points will also be equal and there will be no signal at the output of the phase-sensitive rectifier.

Reference voltages are developed by the a.c. generator, whose rotation is controlled by the same motor which controls the rotation of the counter-reflector of the antenna head. Because of this the frequency of the reference voltage always coincides with the frequency of the conical beam scanning of the radiation pattern.

The reference voltage generator (RVG) develops two sinusoidal voltages 90° apart. One of them is the reference voltage for the azimuth channel; it should coincide in phase (or be 180° out of phase) with the envelope of the azimuth error signal. The second voltage is the reference voltage for the elevation-angle channel. It is selected to coincide in phase (or be 180° out of phase) with the envelope of the elevation-angle error signal.

The envelope of the error signal appearing at the input of the system can generally be represented as the sum of two sine waves having the same frequency but being 90° out of phase, so that each component will coincide in phase (or be 180° out of phase) with the corresponding reference voltage. The amplitudes of the components are proportional to the amount of angular deviation between the axis of the antenna and the direction to the object along the appropriate coordinate, and a change in the direction of the deviation (right or left, up or down) changes the phase of the associated component by 180° (cf. Fig. 9.36).

Separation of the azimuth and elevation-angle error signal and determination of its magnitude and sign takes place in the phase-sensitive rectifiers in the azimuth and elevation-angle tracking channels.

If an error signal voltage appears at the input of the phase-sensitive rectifier, a control voltage appears at its output which depends on the phase shift between the reference voltage and the error signal. If the error signal voltage is in phase with the reference voltage, the current flowing through one shoulder of the phase-sensitive rectifier will increase and the current through the other will decrease. A control voltage with a specific polarity will appear at the output of the rectifier; its magnitude will be proportional to the voltage of the error signal. With a 180° shift in phase of the error signal the current passing through the left shoulder of the phase-sensitive detector increases and the current through the right shoulder decreases. The control voltage at the output of the rectifier will be of the opposite polarity. With a phase shift of 90° between the reference voltage and the error signal voltage the control voltage at the output of the rectifier will be zero, since during each half-cycle of the reference voltage the current in both shoulders of the load changes from maximum to minimum. Consequently, the phase-sensitive rectifier of the azimuth channel reacts only to the component of the azimuth error signal and not to the component of the elevation-angle error.

The rectifier in the elevation-angle channel works similarly.

The rectifier is balanced by potentiometer R2, "Demodulator Balance."

With manual control and automatic sector searching a 400-Hz voltage is used for the reference voltage. The control voltage is fed from the output of the phase-sensitive rectifiers to the two-stage d.c.

amplifiers, and from their output it goes to the control windings of the magnetic power amplifier. A change in the current in the control windings of the magnetic amplifier results in a change in the 400-Hz current in the a.c. windings, which are connected to the control winding of the electric motor drive of the antenna column. The level and phase of the current in the circuit of the a.c. windings in the electric motor and, therefore, its speed and direction of rotation, depend on the level and polarity of the control voltage.

With automatic tracking any deviation of the tracked object from the bi-signal zone leads to the appearance of control voltages. These voltages make the electric motor drives rotate in a direction so that the antenna turns in the direction of the target. When the axis of the antenna system coincides with the direction of the target, the error signal disappears and the control voltage is lifted from the antenna rotors.

Because of the inertia of the system, however, the antenna may go past the precise direction of the target, resulting in the appearance of an error signal of the opposite phase, and this leads to continuous swinging of the antenna.

Negative feedback is used to eliminate the swings. A feedback voltage proportional to the speed of the antenna motion is taken from the tachometer generator of the appropriate channel and fed to the phase-sensitive rectifier of the feedback voltage. This rectifier works the same as the phase-sensitive rectifier for the error-signal voltage.

A 400-Hz voltage goes from the tachometer generator located in the antenna column to the input of the phase-sensitive feedback rectifier. The amplitude of this voltage is proportional to the speed of the antenna, and the phase shifts 180° when the antenna's direction of rotation is reversed.

The magnetic power amplifier unit (cf. Fig. 9.37) supplies the 400-Hz reference voltage to the phase-sensitive feedback rectifier in all modes of operation.

The control voltage goes from the output of the phase-sensitive feedback rectifier to the first d.c. amplifier stage, where it is added to the error-signal voltage. The polarity of the voltage fed to the d.c. amplifier is such that it decreases the level of the control voltage at the output of the d.c. amplifier as the axis of the antenna approaches the direction of the target. As a result the speed of antenna rotation decreases as the antenna approaches the precise direction of the target. After two or three swings the antenna stops precisely in the direction of the target.

Voltage corresponding to the antenna rotation angles along the azimuth and the angle of elevation is taken from the coarse and fine selsyn sensors and fed to the MT-60 data transmission and recording system.

The level of the error signal is checked by two meters located in the azimuth and elevation-angle tracking unit. The voltages fed to these instruments are developed by two phase-sensitive rectifiers whose operation is similar to the operation of the rectifiers described above.

<u>Manual antenna control</u>. With manual control the azimuth and elevation-angle channels are supplied with two independent error signal voltages developed by the selsyn transformers in the antenna control unit. These voltages are created by rotating the handwheels (azimuth or elevation-angle), with which the selsyn transformers are kinematically connected.

Reference voltages are taken from the selsyn sensors located in the antenna column and connected with the azimuth and elevation-angle axes of rotation. The block diagram of the manual antenna control is shown in Fig. 9.40.

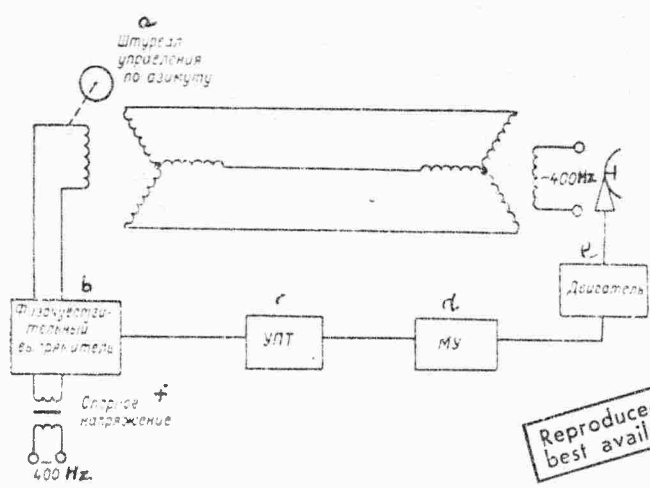

Fig. 9.40. Block diagram of the manual antenna control channel

Key: a. Azimuth control handwheel
b. Phase-sensitive rectifier
c. D.c. amp.
d. MA
e. Motor
f. Reference voltage

The 400-Hz mismatch voltage from the selsyn transformers and the reference voltages from the selsyn sensors are fed to the phase-sensitive rectifiers of the azimuth and elevation-angle channels. A control

voltage appears at the output of these rectifiers whose level depends on the angle of mismatch between the rotors of the selsyns of the particular channel.

The sign of the error voltage depends on the direction the handwheel is turned for a given coordinate.

The control voltage is converted in the same way as with automatic tracking.

Amplified by the magnetic amplifier (MA), the error signal actuates the corresponding antenna motor, and the antenna begins to rotate; it continues rotating until the mismatch signal disappears. The antenna thus turns to the angle specified by the rotor of the selsyn transformer in the antenna control unit.

Automatic sector scanning. With automatic sector scanning the antenna automatically oscillates along the azimuth in sectors of 20° x 20° with a speed of not less than 15 complete oscillations per minute. Simultaneously with the oscillations along the azimuth the antenna may oscillate along the angle of elevation from -3° to 90°. For every five complete azimuth oscillations the antenna makes one complete elevation-angle oscillation. A complete cycle of sector scanning lasts 20 sec.

The antenna is swung along the azimuth and the angle of elevation following a quasi-sinusoidal principle by the automatic sector scanning mechanism. This mechanism includes selsyns for searching the azimuth and the angle of elevation, a search motor connected to selsyns through a reduction gear, and an electromagnetic clutch.

Pressing the "Search" button turns on the electric motor which makes the rotors of the search selsyns turn at a specific speed. The mismatch signal is taken from the selsyns and fed to the phase-sensitive rectifiers in the azimuth and elevation-angle tracking units.

Reference voltages are taken from the selsyn sensors of the antenna column. Further operation of the system is the same as with manual control.

Two limit switches are located in the antenna column to limit the rotation of the antenna along the angle of elevation from -3° to +90°.

A slip ring is used to make the electrical connection between the movable elements of the antenna column and the fixed elements of the station. It consists of 72 silver rings separated by insulating rings. Voltage is taken from the rings by special contact brushes attached to insulated panels.

Test Questions

1. List the basic tactical and technical specifications of the station.

2. What systems does the station include?

3. Draw a block diagram of the transmitting system. How does the transmitter modulator work?

4. What is the discharge chamber and how does it work?

5. Draw a block diagram of the input device unit. What is the reflex klystron used for?

6. Name the main channels of the main amplifier unit.

7. What is the function of the threshhold device circuit?

8. What units does the count system comprise?

9. In what modes does the count system operate?

10. Discuss the operation principles of the main system.

11. What is the calibrator for?

12. How are the type-setting electromagnets for printing meteorological data controlled?

13. Name the modes of operation of the antenna control system.

Chapter 10

The MRL Meteorological Radar Station

In the preceding chapters we considered the radar devices used to determine the meteorological elements (pressure, humidity, and temperature) as well as wind speed and direction at different levels in the atmosphere up to an altitude of 35 or 40 km.

In recent years the hydrometeorological service of the USSR has been using a new meteorological radar (meteorological radiolocation, MRL) station, designed to discover, observe, and determine the location of thunderstorm cells and showers as well as their direction and speed of movement. The MRL is a centimeter-range station and permits determining: 1) the vertical and horizontal elevation of meteorological formations; 2) upper and lower cloud boundaries; 3) the intensity of precipitation and the water content of clouds; 4) the intensity of and tendency for

the development of meteorological formations. The thermodynamic states of the troposphere are also determined (convection zones, ascending air currents, altitude of the tropopause, etc.).

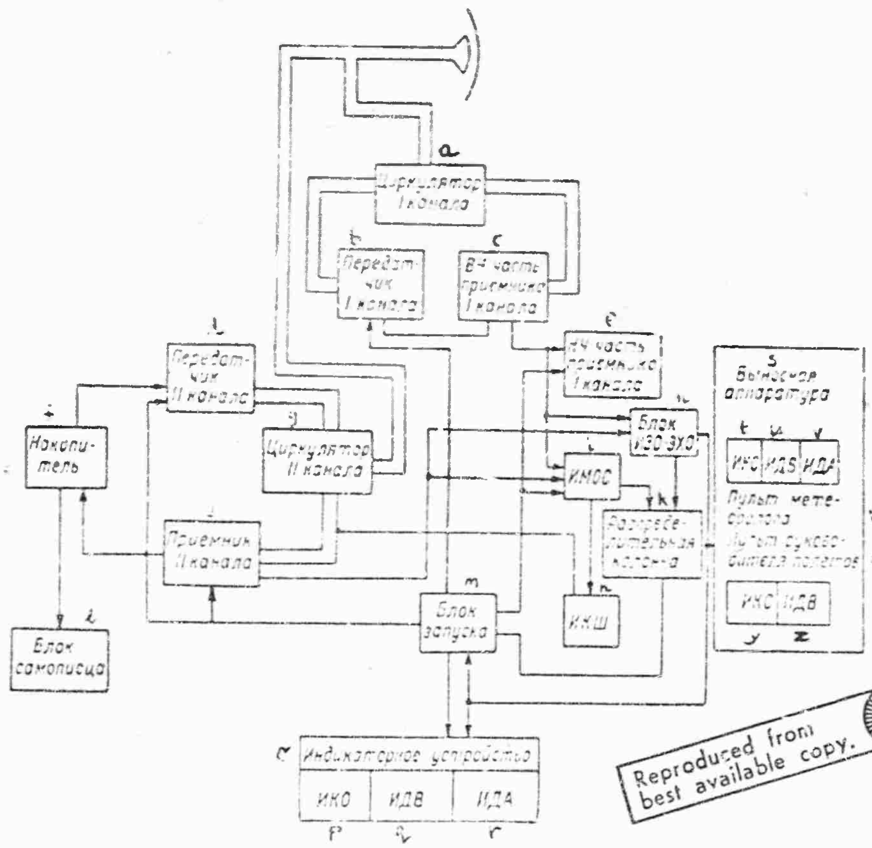

Fig. 10.1. Basic circuit of the MRL-1

Key: a. Channel I circulator
b. Channel I transmitter
c. H.f. section of channel I receiver
d. Channel II transmitter
e. L.f. section of channel I receiver
f. Accumulator
g. Channel II circulator
h. Weather echo
i. RSPI
j. Channel II receiver
k. Switch column
m. Trigger unit
n. NCI

[Key continued on following page]

o. Indicator unit
p. PPI
q. RHI
r. Type A indicator
s. External equipment
t. PPI
u. RHI
v Type A indicator
w. Meteorologist's console
x. Flight director's console
y. PPI
z. RHI

The meteorological radar station is of great help to airport dispatchers in reducing the danger of take-offs and landings of airplanes under complicated meteorological conditions.

BASIC SPECIFICATIONS FOR THE MRL STATION

1.	The transmitting and receiving sections consist of two channels		
2.	Channel I wavelength is in the millimeter range		
3.	Channel II wavelength is in the centimeter range		
4.	Channel I transmitter power		65 kw.
5.	Channel II transmitter power		210 kw.
6.	Blind zone of channel I	no more than	700 m.
7.	Blind zone of channel II	no more than	3000 m.
8.	Radiation pattern width at 0.7 E_{max}:		
	Channel I		13 min.
	Channel II		44 min.
9.	Indicator types: PPI, RHI, type A		

Two variations of the meteorological radar station are produced, a portable unit (MRL-1) and a stationary unit (MRL-2). Unlike the MRL-1 station, the MRL-2 station has only one channel.

The basic circuit of the MRL-1 is shown in Fig. 10.1. The station includes an equipment cabin, which contains the basic station equipment, and an external unit, which contains the meteorologist's and flight director's consoles.

10.1. The Transmitting and Receiving Sections. AFS

The transmitting section (Fig. 10.2). Positive pulses are fed from the trigger unit to the channel I transmitter, which consists of a submodulator, a modulator, and a superhigh-frequency oscillator (a magnetron oscillator).

The submodulator forms the working pulse with a duration of 0.55 µsec. A delay line, a cathode follower, and a paraphase amplifier are used for this. At the output of the amplifier the resulting positive and negative rectangular pulses (which result from subtracting the delayed pulses from the direct pulses) are isolated. The positive pulses are amplified to a level of 1200 v. in the power amplifier (the output stage) and fed to the modulator.

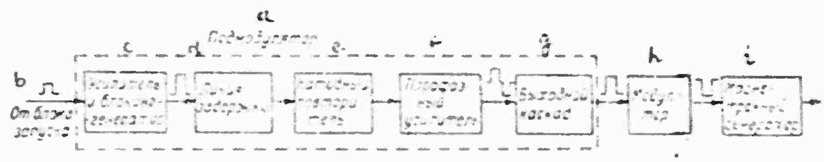

Fig. 10.2. Basic circuit of the Channel I transmitter

Key: a. Submodulator
b. From trigger unit
c. Amplifier and blocking oscillator
d. Delay line
e. Cathode follower
f. Paraphase amplifier
g. Output stage
h. Modulator
i. Magnetron oscillator

The modulator is assembled in a circuit with capacitive storage. When a positive pulse comes from the modulator, the storage capacitor discharges through the tube to the magnetron oscillator. A negative 15-kv. pulse is fed to the cathode of the megnetron oscillator. The duration of the generated pulses is 0.45 µsec., i.e., somewhat less than the duration of the submodulator pulse, since the voltage on the cathode of the magnetron does not increase instantaneously. The s.h.f. signal from the magnetron (P_p = 65 kw.) is fed through the waveguide circuit to the antenna and emitted into space (as a pencil beam).

The channel I transmitter is used for determining the altitude of the lower boundaries of shower-yielding clouds that are located at distances up to 10 km., and also for determining the upper boundaries of dense clouds yielding drizzles.

The channel II transmitter is triggered by a synchronizing pulse of 0.7-1 µsec. duration from the trigger unit. The circuit of the channel II transmitter is similar to the circuit of the channel I transmitter. The distinctive feature of the submodulator is that positive pulses of various durations (1.1, 2.1, and 0.9 µsec.) can be taken from its output for operating the MRL in the "Tune," "Local," and "Distant" modes. The channel II transmitter is used for discovering showers and thunderstorms within a radius of 300 km.

The receiving section, like the transmitting section, consists of two channels. The channel I receiver operates with the channel I transmitter, and the channel II receiver operates with the channel II transmitter.

The channel I receiver is assembled in a superheterodyne circuit and is designed to isolate, convert, and amplify the signals reflected from meteorological formations to the necessary level (Fig. 10.3).

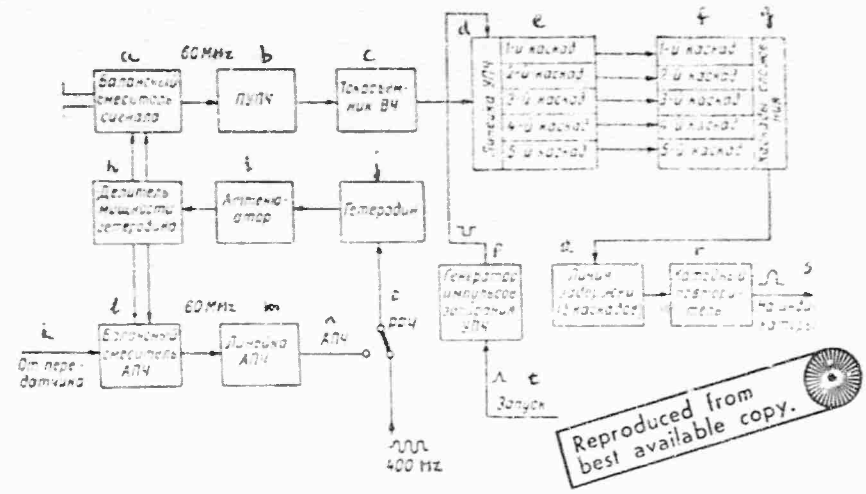

Fig. 10.3. Basic circuit of the Channel I receiver

Key: a. Balance signal mixer
- b. I.f. preamplifier
- c. H.f. slip ring
- d. I.f. amp. bus
- e. 1-st stage, 2-nd stage, etc.
- f. 1-st stage, 2-nd stage, etc.
- g. Adder stages
- h. Heterodyne-power divider
- i. Attenuator
- j. Heterodyne
- k. From transmitter
- l. Balance AFC mixer
- m. AFC bus
- n. AFC
- o. MFC
- p. I.f. blocking pulse generator
- q. Delay line (5 stages)
- r. Cathode follower
- s. To indicators
- t. Trigger

A signal picked up by the antenna goes through the waveguide circuit to the h.f. section, which consists of segments of waveguides and contains two balance mixers (for the signal and the AFC) which are supplied by a single local oscillator; a power divider for the local-oscillator signal is provided in the circuit.

The incoming reflected signal and the local-oscillator signal, whose frequency is 60 MHz above that of the reflected signal, are fed simultaneously to the signal mixer. The 60-MHz i.f. signal appears at the output of the signal mixer and is then fed to the input of the two-stage i.f. preamplifier. The i.f. preamplifier is assembled in a low-noise grounded-cathode grounded-grid circuit.

The amplified signal then goes through the high-frequency slip ring through a cable to the i.f. channel divider. From the output of the divider the signal voltage goes to the i.f. amplifier bus and to the reflected-signal-power indicator unit (RSPI). A special characteristic of the i.f. amplifier is that it can operate in two modes, linear and logarithmic.

In the linear mode amplification takes place in five stages, after which the signal is detected and amplified by the video amplifier and fed to the indicator unit, which consists of a plan position indicator (PPI), a range-height indicator (RHI), and a double-beam amplitude indicator with straight sweep (the type A indicator). The loragithmic operation of the i.f. amplifier provides attenuation for strong reflected signals and amplification of weak ones. The amplification and attenuation of incoming signals is logarithmic and is performed by the detector and adder circuits.

The i.f. amplifier operates in the logarithmic mode as follows. After conversion the reflected signal is amplified by the five i.f. stages and then detected. From the output of each stage (of the five detectors) the signals are fed to the input of the five adder stages, which operate only logarithmically and which are switched in by a relay. The adder stage is a video amplifier whose load is the delay line. In the delay line all the signals are added and the resulting positive signal is fed from the output of the line through a cathode follower to the indicator device.

A special negative pulse generator (the i.f. amplifier blocking-pulse generator) is provided in the circuit for blocking the receiver when the transmitter is in operation. The generator is triggered by positive pulses with a frequency equal to the repetition frequency of the transmitter sounding pulses. A negative pulse with a specific amplitude is fed from the output of the generator to the control grid of the first i.f. amplifier stage and blocks it.

The channel I receiver section includes an automatic frequency control circuit to provide a constant i.f. signal of 60 MHz.

The AFC circuit includes an attenuator, an AFC balance mixer, a discriminator, and a video amplifier.

Let us examine the operation of the AFC circuit (Fig. 10.4).

The high-frequency channel I transmitter signal is reduced by the attenuator and fed to the AFC balance mixer. A high-frequency signal with a frequency of 60 MHz above the transmitter frequency is simultaneously fed to this mixer from the local-oscillator power divider. The i.f. signal from the output of the AFC mixer is amplified in the i.f. amplifier and fed to the input of the discriminator. The difference signal, whose amplitude and polarity depend on the amount of deviation of the intermediate frequency from 60 MHz, is taken from the load of the discriminator. This signal goes to the video amplifier and then to the peak detector of the local oscillator. The peak detector develops a constant control voltage that is fed to the local oscillator and sets its frequency 60 MHz above that of the signal.

The heterodyne frequency may also be tuned manually This is accomplished by using a potentiometer to regulate the level of the alternating (400-Hz) voltage at the peak detector.

The circuit and operation of the channel II receiver are similar to the circuit and operation of the channel I receiver, so we shall indicate here only certain differences between these channels.

The channel II receiver includes a high-frequency amplifier assembled in a traveling wave tube to increase the sensitivity of the device. The signal from the output of the traveling wave tube goes through the waveguide circuit to the mixer. The 60-MHz i.f. signal goes to two i.f. preamplifier stages, and then through a cable to the input of the i.f. amplifier and the input of the i.f. channel divider.

The i.f. amplifier, just as the channel I amplifier, can operate linearly and logarithmically. Provision is made in the i.f. amplifier for manual gain control (by changing the negative voltage on the control grid of the first i.f. amplifier stage). The circuits for automatic frequency control and receiver protection from the powerful transmitter pulses are similar to the circuits in channel I.

The weather-echo unit, the RSPI unit, and the accumulator can also be included in the receiving section.

The <u>weather-echo unit</u>. As is generally known, the method used in meteorological radar stations to record and process information is that in which the radar signal reflected from meteorological formations, corrected for the square of the distance, and exceeding a fixed level are limited and fed to the plan position indicator (PPI).

The weather-echo unit accomplishes this signal conversion in the MRL; the reflected signals are fed to the input of this unit from the output of the channel II receiver. Video signals limited to the level of the weather echo and amplified go from the output of this unit to the indicator device and the trigger unit, where they are mixed with the trigger pulses. The mixed pulses go to the external indicators (the meteorologist's console). Areas of the most intensive meteorological formations will be isolated on the indicator screens. The intensity is determined by an instrument located in the trigger unit.

The weather-echo unit is also designed for checking the operating modes of the transmitters of both channels. Instruments located in this unit duplicate the indications of instruments located in the transmitting system.

The accumulator device. Every radar receiver has internal noise. If a signal picked up by the antenna is below the internal noise of the receiver, the receiver circuit will not be actuated. Cases can be observed in the operation of the MRL when the amplitudes of signals reflected from meteorological formations are very small. The radar station includes an accumulator for discovering such formations; this device accumulates the reflected signals whose amplitude is significantly below the amplitude of the internal noise of the receiver section.

A modulated method for increasing the sensitivity of the radar receiver, which is based on improving the signal-to-noise ratio, is used in the accumulator device. Increased sensitivity is achieved by increasing the time for observing the meteorological formations.

The accumulator device consists of a forming unit, an accumulator unit, and an automatic recorder unit. From the second stage of the i.f. preamplifier of the channel II receiver the signal goes to the forming unit. Amplification of the i.f. signals, their time selection, and the formation of calibration marks and a gated signal occur in this unit. The signal-to-noise ratio (V_s / V_n) is improved in the accumulator unit. A constant voltage proportional to the incoming useful video signal is taken from the output of this unit.

The pulses from the accumulator unit are fed to the station trigger and also to the recorder unit for recording the amplitudes and shapes of the pulses. A simplified block diagram of the accumulator device is shown in Fig. 10.5.

The reflected-signal power indicator (RSPI). The meteorological radar station includes equipment for measuring the power of signals reflected from clouds and precipitation. The RSPI unit takes comparative measurements of signal power at a trigger pulse repetition frequency of 300 and 600 p/s.

The power of signals reflected from clouds and precipitation must be measured in order to evaluate their intensity and discriminate between showers and thunderstorms.

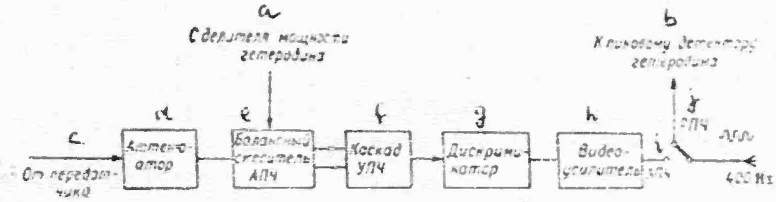

Fig. 10.4. Block diagram of the AFC

Key: a. From local-oscillator power divider
b. To local-oscillator peak detector
c. From transmitter
d. Attenuator
e. AFC balance mixer
f. I.f. amplifier stage
g. Discriminator
h. Video amplifier
i. AFC
k. MFC

A block diagram of the RSPI unit is shown in Fig. 10.6. I.f. signals from the channel I and channel II receivers appear at the input of this unit. Signals from either channel I or channel II appear at the input of the attenuator depending on the position of the switch ("Channel I" or "Channel II"). During this time the i.f. signals from the receiver of the other channel are grounded. The attenuator is designed to provide calibrated attenuation of the i.f. signals.

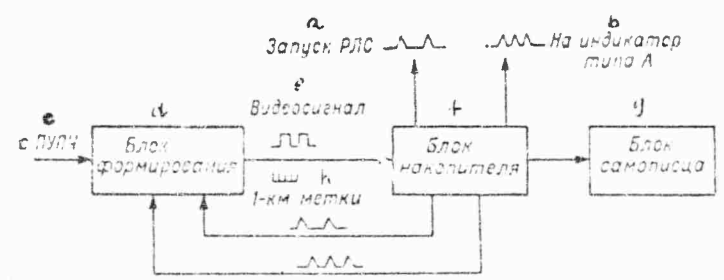

Fig. 10 5. Block diagram of the accumulator unit

Key: a. Station trigger
b. To type A indicator
c. From i.f. preamplifier
d. Forming unit
e. Video signal

[Key continued on following page]

f. Accumulator unit
g. Recorder unit
hl 1-km. marks

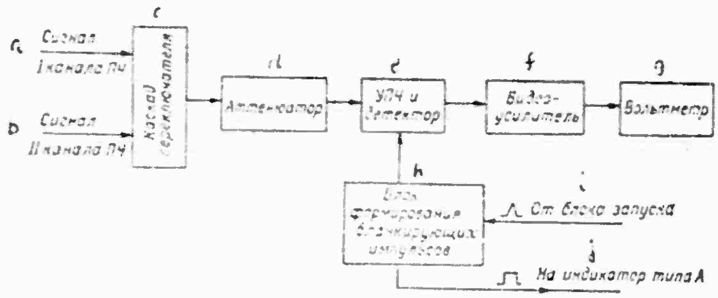

Fig. 10.6. Block diagram of the RSPI unit

Key: a. Channel I i.f. signal
b. Channel II i.f. signal
c. Switch stage
d. Attenuator
e. I.f. amp. and detector
f. Video amp.
g. Voltmeter
h. Blanking-pulse forming unit
i. From trigger unit
j. To type A indicator

The power of the reflected signal is measured by comparing this signal with the level of the internal receiver noise (the reference level). This level is strictly established for every station.

The signal goes from the output of the attenuator to the stage containing the i.f. amplifier and the detector.

The blanking-pulse forming unit develops negative pulses for blocking the i.f. amplifier during the transmitter sounding pulse, and positive pulses from this unit unblock the i.f. amplifier at the time the power of the reflected signal is measured.

A positive pulse is fed to the type A indicator to isolate the necessary signal of the target.

The detected i.f. signals go to the video amplifier, which increases the amplitude of the signals to a level measurable by the peak voltmeter.

The peak voltmeter, in whose load circuit a microammeter is connected, is used to compare the power level of the reflected signal with the reference level.

Besides these units, the MRL includes equipment for measuring the noise figure of the receiver and a photographic recording device.

As is generally known, the noise figure shows how much the signal-to-noise ratio is decreased as the signal passes through the receiver circuit. The noise figure is measured at the output of the receiver i.f. preamplifier, since its value is determined chiefly by the noise figure of the traveling wave tube, the mixer, the local oscillator, and the i.f. preamplifier.

The photographic recording equipment photographs the meteorological situation within the range of operation of the station on the PPI, RHI, and type-A indicator screens. These photographs are later used to confirm the correctness of the methods used in making the observations. Single-frame photographs are made from the PPI, RHI, and type A indicator screens, and a continuous 35-mm. film may be made of the RHI screen.

The FARM 2A automatic camera is used for the photographic recording.

The <u>antenna feeder system</u> (AFS). The antenna of the MRL-1 radar station is of a parabolic type and has two ranges. The parabolic reflector is a paraboloid with an opening 3 meters in diameter. A dual exciter is used. The two horns of the exciter are built into each other so that their openings lie in the same plane and their radiation centers coincide.

Waveguides are used to transmit the high-frequency pulses from the transmitter to the antenna and the reflected signals picked up by the antenna to the receiver.

The antenna feeder system consists of two channels and allows the radar station to operate in the following modes: panoramic horizontal scanning; vertical scanning; vertical sounding with a fixed beam along the angle of elevation from -1° to 105°; stepped scanning along the angle of elevation and the azimuth.

Since the receiving and transmitting equipment of channel I is located in the rotating part of the antenna system and the channel II equipment is located in the equipment cabin, a rotating waveguide transition (slip ring) is connected on the axis of the antenna rotation.

Ferrite circulators function as the antenna switch of the MRL centimeter range.

The AFS also includes a double directional coupler, which is made of waveguide segments, and an attenuator. The coupler directs the high-frequency energy to the AFC circuit, and the attenuator regulates the level of energy shunted from the main channel.

10.2. Indicator Devices

The indicator devices of the MRL radar station can be divided into two groups. The first group, the control group, is located in the equipment compartment. It includes a PPI, a RHI, and a type A indicator. The second group, the external equipment, is located no more than one kilometer from the MRL. This group includes a PPI, a RHI, and an amplitude range indicator. These indicators are installed in a single console for the meteorologist. Besides the indicators, the external equipment also includes the photographic recording equipment and the flight director's console. The corresponding indicator devices of the control equipment and the meteorologist's console are constructed with the same circuits and have identical functions.

The PPI is designed to produce on a c.r.t. screen radar representations of a meteorological formation in polar coordinates in terms of azimuth and range. The PPI has a bright marker with long persistence, i.e., the image of this formation remains on the screen for some time.

The PPI has three fixed range scales of 25, 100, and 300 kilometers. The beginning of the sweep on the screen may be shifted. The location of meteorological formations is determined by their position on the indicator screen relative to the range marks. The azimuth is determined by a dial device.

The range-height indicator is used to supply the c.r.t. screen with radar reflections of meteorological formations lying within the MRL visibility range in terms of range and altitude coordinates. The vertical profile of clouds and precipitation can be viewed on this indicator. The rotation of the sweep is synchronized with the scanning of the antenna along the angle of elevation. The vertical angle of the antenna corresponds to the angle of slant of the sweep line at all times.

The RHI has four fixed scales of 5, 10, 20, and 40 kilometers and corresponding height scales of 2.5, 5, 10, and 20 kilometers. The height and depth of the meteorological formations as well as their distance from the MRL are determined relative to the range and height marks on the scale.

The double-beam type A amplitude indicator (straight sweep) is designed for observing signals reflected from meteorological formations as well as for determining the amplitude and the time relationships

between these signals. On this indicator the range of the meteorological formations is determined by the distance between the beginning of the vertical sweep and the vertical burst (the reflected signal) on this sweep. Since there are two operating channels in the MRL radar station, the signals from channel I and channel II can be observed simultaneously on both sweeps of the double-beam indicator, and individual sections of the sweep can be observed on a large scale.

The <u>plan position indicator</u>. The functional diagram of the PPI circuit is shown in Fig. 10.7.

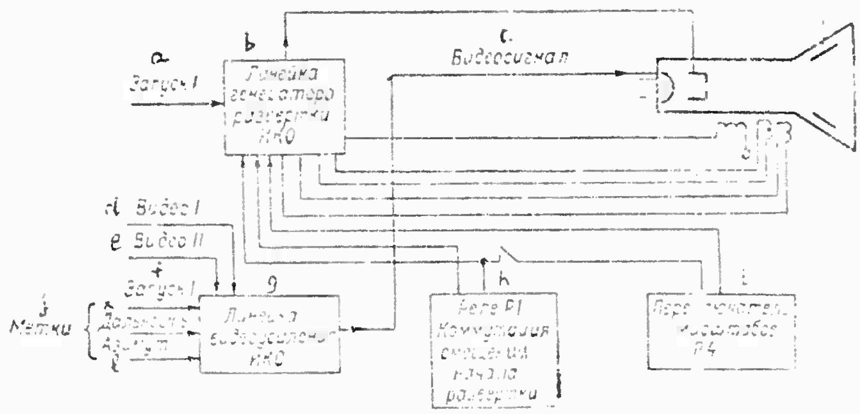

Fig. 10.7. Functional diagram of the PPI

Key:
- a. Trigger I
- b. PPI sweep generator bus
- c. Video signal
- d. Video I
- e. Video II
- f. Trigger I
- g. PPI video signal bus
- h. Relay P1, switching the position of the beginning of the sweep
- i. Scale switch, B4
- j. Marks
- k. Range
- l. Azimuth

The sweep generator bus develops positive and negative pulses whose duration corresponds to the three scales of sweep (25, 100, and 300 km.). Trapezoidal voltage pulses whose amplitude varies as the sine and cosine of the angle of antenna rotation are later formed in the bus from these pulses. These pulses are then converted to sawtooth pulses of the opposite phase, which are needed for feeding the deflecting coils.

The channel I and channel II signals as well as the range and azimuth scale marks are fed to the input of the video amplifier bus. This bus is designed to mix and amplify the video signals and scale marks, and also to suppress the interference arising during the operation of the channel I transmitter. From the output of the bus the video signal goes to the cathode of the c.r.t.

Relay P1 is used for switching the circuits and shifting the beginning of the sweep to any point on the screen with the 100-km. and 300-km. scales.

Switch B4 selects the desired sweep scale on the PPI for observing the signals reflected from meteorological formations.

Let us consider the simplified block diagram of the sweep generator bus (Fig. 10.8). The sweep generator channel is triggered by a positive pulse which goes to the buffer amplifier. In this stage the trigger pulses are amplified, changed in phase, and fed in negative polarity to the flip-flop multivibrator, which functions as a pulse stretcher. The duration of the multivibrator pulses can be varied using the switching device connected with the scale switch. The duration of these pulses is strictly controlled at 180, 700, and 2400 µsec., which corresponds to the range scales on the PPI (25, 100, and 300 km.). From the output of the multivibrator positive pulses go to the phase inverters and into the sweep-dimming channel.

The sweep-dimming channel is assembled as a cathode follower from whose output positive rectangular pulses go to the c.r.t. modulator for dimming the retrace of the sweep.

The phase inverters are designed to convert the rectangular pulses coming from the multivibrator to negative and positive pulses. Since identical load resistors are connected in the plates and cathodes, the amplitudes of these pulses will be identical. The output pulses of the phase inverters go to the trapezoidal-voltage generators and trigger them.

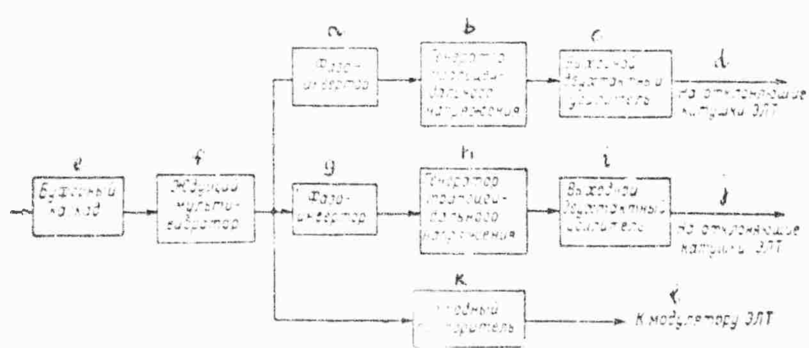

Fig. 10.8. Block diagram of the PPI sweep generator bus
[Key on following page]

Key: a. Phase inverter
b. Trapezoidal-voltage generator
c. Final push-pull amplifier
d. To c.r.t. deflection coils
e. Buffer stage
f. Flip-flop multivibrator
g. Phase inverter
h. Trapezoidal-voltage generator
i. Final push-pull amplifier
j. To c.r.t. deflection coils
k. Cathode follower
l. To c.r.t. modulator

The trapezoidal-voltage generators are designed for forming trapezoidal pulses which, after amplification in the push-pull amplifier stages, create a linearly increasing sawtooth current in the c.r.t. deflecting system.

The video amplifier bus includes a channel of video amplification and interference suppression, which is designed for mixing and amplifying the video signals and range- and azimuth-scale marks, and also for suppressing interference arising from the operation of the channel I transmitter.

A 31LM32V cathode ray tube is used in the PPI of the MRL. The deflection system is fixed and consists of horizontally and vertically deflecting coils. The vertical deflection coils are fed by a sawtooth current whose level is proportional to the cosine of the antenna rotation angle, and the horizontal deflection coils are fed a sawtooth current whose level is proportional to the sine of the antenna rotation angle.

A rotating magnetic field is created as a result of the interaction of the megnetic fields of the coils, with the result that the electron beam scans along the radius of the screen, and the sweep line shifts in synchronization with the rotation of the antenna.

Focusing of the c.r.t. electron beam is done with the focusing coil and the focusing stage by varying the current flowing through the coils. The current level is regulated by a potentiometer, whose knob is brought out to the front panel and is labeled "Focus."

The brightness of the image and the brightness of the azimuth and range marks on the screen of the indicator can be varied using specific regulating circuits.

Moreover, provision is also made for regulating the amplitude of the video signal to the PPI, centering the start of the sweep, and displacing the beginning of the sweep from the center of the shift of the sweep.

The range-height indicator. The circuit of the range-height indicator includes a sweep generator bus, a video amplifier bus, regulating circuits, bias for the center, brightness, focus, and amplitude of the sweep, the delay of the sweep, the brightness of the range marks, and the amplitude of the "video."

Let us consider the functional diagram of the sweep generator bus (Fig. 10.9).

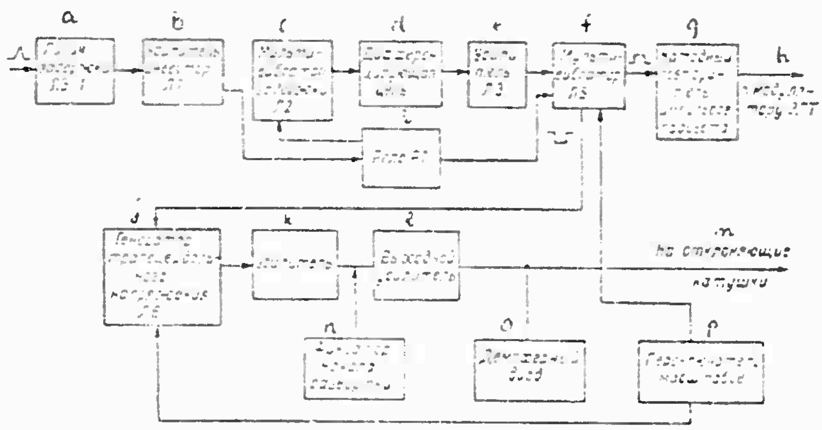

Fig. 10.9. Functional diagram of the sweep generator bus of the PPI

Key: a. Delay line, DL-1
b. Amplifier/inverter, V1
c. Delay multivibrator, V2
d. Differentiating circuit
e. Amplifier, V3
f. Multivibrator, V5
g. Dimming pulse cathode follower
h. To c.r.t. modulator
i. Relay, P1
j. Trapezoidal-voltage generator, V6
k. Amplifier
l. Final amplifier
m. To deflection coils
n. Sweep start locator
o. Damping diode
p. Scale selector

Positive pulses from the trigger unit go to the DL-1 delay line, which causes the beginning of the sweep on the indicator to coincide in time with the transmitter sounding pulse by delaying the pulses that trigger the sweep generator. From the delay line the pulses go to the amplifier/inverter (V1), where the pulses are amplified and shifted to the opposite phase. From the output of the amplifier/inverter trigger pulses go either to the delay multivibrator (V2) or the multivibrator (V5).

If the "Delay-Defl." switch on the front panel of the RHI is in the "Delay" position, relay P1 closes and pulses from the inverter trigger the delay multivibrator at V2, which develops rectangular pulses with a variable duration (from 3 to 30 μsec.). Positive pulses from the plate load of the multivibrator go to the differentiating circuit, at whose output short-duration positive and negative pulses are formed. The positive pulses are limited and the negative pulses go to the grid of the amplifier (V3).

The negative pulses from the plate load go to the multivibrator (V5) and trigger it. The multivibrator develops positive and negative rectangular pulses. The duration of these pulses can be varied (40, 80, 160, or 300 microseconds) and depends on the position of the scale selector switch (5, 10, 20, and 40 km.), respectively.

From the output of V5 the negative pulses go to the trapezoidal-voltage generator at V6, and the positive pulses go to the dimming-pulse cathode follower. The trapezoidal-voltage generator converts the rectangular pulses into trapezoidal ones, which are necessary for the sweep to appear on the screen of the RHI. Like the duration of the multivibrator pulses, the duration of the output pulses from the generator changes when the position of the scale selector is changed.

From the output of the generator pulses go to the three-stage amplifier, which is designed to amplify the voltage pulses and convert them to sawtooth current pulses in the deflection coil.

To limit the positive voltage spikes at the deflection coil during the sweep retrace, the circuit incorporates a sweep-start voltage clamper, which is cut off during the rightward sweep by the negative trapezoidal pulses.

When the "Delay-Defl." swithc is in the "Defl." position, the output of the amplifier/inverter is connected through relay P1 to the multivibrator at V5. The operation of the remaining stages is no different than their operation when the switch is in the "Delay" position.

A c.r.t. with electromagnetic beam deflection (31LM32V) is used in the range-height indicator. Synchronized in time and phase, the deflection coil repeats the swinging of the antenna. For this a

synchronous coupling system is used which includes a selsyn sensor, a selsyn receiver (the control linkage of the deflection coil), and a synchronizing device.

The rotor of the selsyn sensor is mechanically connected with the axis of the antenna, and the angular position of the antenna is transmitted to the selsyn receiver and then to the rotating coil of the deflection system (the rotor of the selsyn is connected to the coil). The selsyn sensor and the selsyn receiver operate in the indicator mode. A phasing system is used in the selsyn transmission to provide cophasal rotation of the coil and the swinging of the antenna.

To provide raster (line) scanning the beginning of the sweep is shifted from the center to the edge of the tube using a shift coil and a special potentiometer, "Center Shift," located on the front panel of the RHI.

In the RHI tube unit there are also circuits for regulating the image focus, range-mark intensity, video signal amplitude, brightness of the scale illumination, etc.

The scale device is designed for reading off the range or height of meteorological formations from a mechanical scale indicating the position of the antenna.

The <u>double-beam type A amplitude indicator</u>. The type A indicator in the radar station is designed for examining the video signals of channel I, channel II, or channel II and II simultaneously. The indicator circuit consists of two independent channels, one for each beam of the tube. Each channel contains a range-mark generator and a video amplifier.

The sweep of the first beam can be delayed relative to the transmitter sounding pulse. The sweep of the second beam is triggered in synchronism with the emission of a transmitter pulse in all three modes of operation of the indicator.

Fig. 10.10 shows a simplified diagram of the indicator (one channel); the stages of the other channel and their operation are similar to those in this figure.

The station trigger pulses (trigger I and trigger II) go through the switching unit (P2-P5) to the trigger with the trigger tube (V1 and V2), which trips and triggers the linearly increasing-voltage (LIV) generator. When this voltage reaches the tripping level, the trigger returns to its original (initial) state. The pulses go from the output of the trigger to the sweep-dimming channel, assembled in a cathode follower (V8). Positive pulses go from the cathode load to the control electrode of the c.r.t. to dim the retrace.

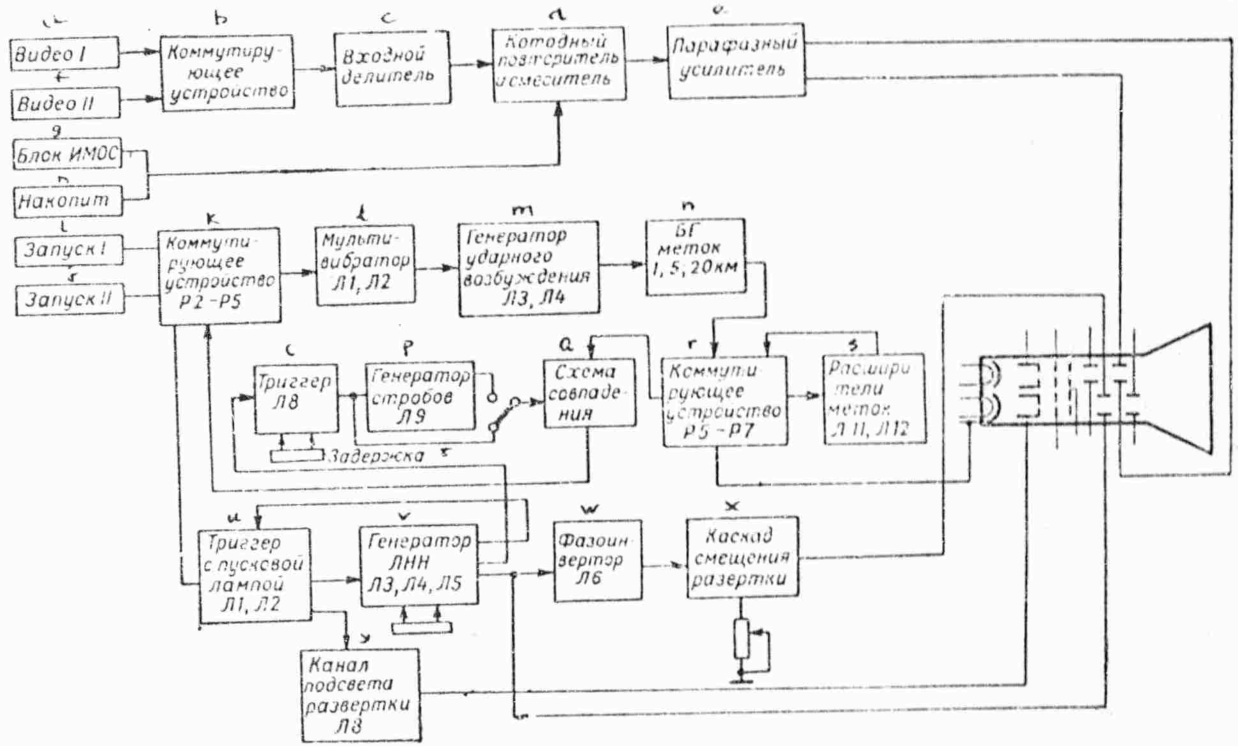

Fig. 10.10. Functional diagram of the type A indicator

[Key on following page]

Key: a. Video I
b. Switching unit
c. Output divider
d. Cathode follower and mixer
e. Paraphase amplifier
f. Video II
g. RSPI unit
h. Accumulator
i. Trigger I
j. Trigger II
k. Switching unit, P2-P5
l. Multivibrator, V1, V2
m. Impact-excitation oscillator, V3, V4
n. 1-, 5-, and 20-km. mark blocking oscillator
o. Trigger, V8
p. Gate generator, V9
q. Coincidence circuit
r. Switching unit, P5-P7
s. Mark expander, V11, V12
t. Delay
u. Trigger with trigger tube, V1, V2
v. LIV generator, V3, V4, V5
w. Phase inverter, V6
x. Sweep-shift stage
y. Sweep-dimming channel, V8

The output pulses from the LIV generator go to one of the horizontal deflection plates and to the phase inverter (V6). From the output of the phase inverter negative pulses are fed to the stage that shifts the sweep horizontally on the c.r.t.

From the switching unit (P2-P5) the trigger pulses also go to the input of the multivibrator (V1, V2), which is the first stage of the channel that forms the range-mark pulses. Negative rectangular pulses from the output of the multivibrator trigger the impact-excitation oscillator (V3, V4), whose output signals are fed to the blocking oscillator for the 1-, 5-, and 20-km. marks.

The range marks from the blocking oscillator pass through the switching unit (P5-P7) to the cathode of the c.r.t., the range marks for the 5- and 20-km. scales being preliminarily expanded by the flip-flop multivibrator (V11, V12) so as to be more clearly distinguishable when the larger sweep scale is switched in.

The following stages operate in the circuit in order to delay the sweep-triggering pulse for the first beam relative to the sounding pulse: a Schmidt trigger (V8), a gate generator, and a coincidence circuit.

From the output of the LIV generator (V4) a positive voltage goes to the input of the Schmidt trigger at the same time as the reference voltage (from the "Delay" potentiometer). When the positive sawtooth voltage from the LIV generator exceeds the reference voltage, the trigger trips and at its output there appears a pulse delayed relative to the trigger pulse by a value proportional to the value of the reference voltage.

When the indicator is operating with a discrete delay, the pulse from the trigger triggers the gate generator (V9), assembled as a flip-flop multivibrator. The gate is generated in this stage, and, when it coincides with one of the range-mark pulses, a pulse coinciding in time with this range mark appears at the output of the generator. Through the switching unit this pulse then triggers the sweep generator of the first beam.

The video signals from the receiving section of the MRL go through the switching unit, which allows passage of signals from channel I, channel II, or both channels together, to the input of the divider, where their amplitude can be decreased by a factor of 10 or 100.

The signal mixer, which is assembled as a cathode follower, receives video signals from the divider and blanking pulses from the reflected-signal power indicator (RSPI) and the accumulator. The mixed signals go to the paraphase amplifier and then to the vertical deflection plates of the c.r.t.

A 16LO24 (double-beam) cathode ray tube is used in the type A indicator. Located on the front panel of the unit are regulating and controlling knobs for the two beams, "Intensity I," "Intensity II," "Focus I," "Focus II," "Shift X," and "Shift Y."

10.3. Radar Acquisition of Meteorological Formations

In deriving the basic radar equation in Chapter I we accepted the definition that the target has an effective surface, S_e. The radar equation (1.14) in such a form is usually used for single targets (an airplane, a rocket, a ship, etc.).

In meteorological radar, however, it is very important to know the effective surface not of a single target but of a meteorological formation that must be acquired. This is connected with the fact that, no matter how narrowly directed an antenna a meteorological radar station may have, the radiation pattern "illuminates" simultaneously a certain number of individual targets (reflectors) which is determined by the width of the antenna pattern and the length in space of the pulse. Therefore, the power of an incoming reflected signal must be viewed as power reflected from a large number of individual targets.

Since the speed of movement of meteorological formations is not great, the power of the reflected signals during a specific time period can be averaged. Using Formulas (1.13) and (1.14), we obtain

$$P_{пр} = \frac{P_{изл} A^2}{9\pi\lambda^2 R^4} \sum_{1}^{N} S_э \qquad (10.1)$$

пр = rec
изл = rad
э = e

where $A = \frac{3\lambda^2 G}{8\pi}$ is the antenna aperture. The summation here is over some volume of mass V_m, which is determined by the width of the radiation pattern:

$$V_m = \pi \left(R \frac{\theta_в}{2}\right)\left(R \frac{\theta_г}{2}\right) \frac{t_и}{2} \qquad (10.2)$$

в = v
г = h
и = p

where θ_v and θ_h are horizontal and vertical widths of the beam in radians, and t_i is the duration of the sounding pulse in seconds.

The total cross section of the backscatter (S) can be defined as the cross section of a single volume multiplied by volume V_m.

If the clouds and precipitation consist of spheric particles whose diameters are significantly less than the length of the wave, the effective surface of the scatter from a single particle is expressed by the formula

$$S_i = \frac{\pi^5 d_i^6}{\lambda^4} \left(\frac{m^2 - 1}{m^2 + 2}\right)^2 \qquad (10.3)$$

where d_i is the diameter of the particle in centimeters, λ is the wavelength in centimeters, m is the aggregated factor of the refraction of the water, ice, or gas, and $\left(\frac{m^2 - 1}{m^2 + 2}\right)^2$ depends on the dielectric constant of the atmosphere.

Inserting the value of V_m and Formula (10.3) into Formula (10.1), we obtain

$$P_{пр} = \left(\frac{\pi^5}{72} \frac{P_{изл} A^2 \theta_в \theta_г h}{\lambda^6}\right) \left(\frac{m^2 - 1}{m^2 + 2}\right)^2 \frac{\sum_{1}^{N} N_i d_i^6}{R^2} \qquad (10.4)$$

пр = rec
изл = rad
в = v
г = h

Taking the attenuation factor into account, we can rewrite this equation as

$$R^2 = \left(\frac{\pi^5 P_{\text{изл}} A^2 \theta_{\text{в}} \theta_{\text{г}} h}{72 P_{\text{пр}} \lambda^6}\right)\left(\frac{m^2-1}{m^2+2}\right)^2 \sum_1 S_i K K_{\text{з}} \qquad (10.5)$$

изл = rad
в = v
г = h
пр = rec
з = ch

where P_{rec} is the power of the received signal reflected from a meteorological formation (in watts), P_{rad} is the transmitter radiated power (in watts), A is the antenna aperture (in square meters), λ is the wavelength (in meters), R is the distance between the radar station and the formation, K is the attenuation factor of the radio wave, K_{ch} is the factor characterizing the charge of the sounding pulse by particles of clouds and precipitation, and h is the length of the sounding pulse (in meters).

Equations (10.4) and (10.5) are the <u>basic equations for radiolocation of meteorological formations</u>.

The maximum range for the detection of formations can be determined from the formula

$$R_{\text{макс}} = \sqrt{\left(\frac{\pi^5 P_{\text{изл}} A^2 \theta_{\text{в}} \theta_{\text{г}} h}{72 P_{\text{пр.мин}} \lambda^6}\right)\left(\frac{m^2-1}{m^2+2}\right)^2 \sum_1 N_i d_i^6 K K_{\text{з}}} \qquad (10.6)$$

макс = max
изл = rad
в = v
г = h
пр.мин = rec.min

In this formula the reflected signal power (P_{rec}) is assumed to be equal to the receiver sensitivity ($P_{rec.\,min}$). The power of an incoming signal is inversely proportional to the square of the distance and not to the distance to the fourth power, as we have shown in Chapter I. This is because the number of reflecting particles increases proportional to the square of the distance from the station.

From Formula (10.6) it is clear that the diameter of the particles has a strong influence on the power of the received signal, since it appears to the sixth power in the formula. An increase in particle diameter by a factor of two results in an increase in the power of the received signal by a factor of 64.

As the wavelength decreases, the probability of detecting fine particles increases, since the power of the received signal is inversely proportional to the sixth power of the wavelength.

In order for one meteorological radar station to detect precipitation areas and cloud zones, modern radars operate with two ranges, the centimeter range and the millimeter range.

The reflectivity of clouds and precipitation depends on the number of drops and the diameter of the particles:

$$Z = \sum_{1}^{N} N_i d_i^6 \qquad (10.7)$$

For moderate latitudes $Z = 220\ I^{1,6}$, where I is the intensity of rainfalls in mm./h.

The effective surface of cloud scattering is expressed as

$$S_{cl} = 13.2 \cdot 10^{-8} \frac{W^2}{\lambda^4} (M^{-1}) \qquad (10.8)$$

and the surface of precipitation scattering is expressed as

$$S_{pr} = 6.2 \cdot 10^{-4} \frac{I^{1.6}}{\lambda^4} (M^{-1}) \qquad (10.9)$$

where W and I are the water content of the clouds and the intensity of the rainfall.

Using the formula for the range of radar detection of meteorological formations, we can determine the intensity of precipitation and the water content of clouds from the power level of the received signal.

A meteorological radar station (MRS) permits detection of the horizontal distance (D_h) of thunderstorm and shower cells. The MRS can also be used to determine the shape and cross section of a meteorological formation in the horizontal and vertical planes, the direction and speed of its movement, the tendency for it to develop, and the intensity of the rainfall. The azimuth of the formation is found from the position of the antenna.

The MRS is also used by airport dispatchers for take-offs and landings under complicated meteorological conditions.

Let us consider only questions connected with meteorological service, i.e., the observation of meteorological formations.

The place for setting up a radar station is selected so as to give a good view in all directions and so that its antenna is sufficiently elevated above local objects. For the stationary variant of the MRS a special (standard) building is constructed to house the equipment.

After the MRS is established and oriented, local objects situated in the area of the station are found and studied. To do this the station is turned on and the azimuth and distance of the local objects

are noted on the PPI screen; the PPI "picture" is then photographed. This photograph is later used (in station operations) to distinguish the image of clouds, precipitation, and other formations from the local objects.

To provide maximum range for detecting continuous precipitation and thunderstorm and shower cells the MRS begins operating on channel II even during the panoramic scanning, and the transmitter transmits 2-μsec. inquiry pulses at a rate of 300 p/s.

The scale for the 0-300-km. range should be set up on the indicator. The MRS antenna is smoothly rotated along the azimuth from 0° to 360°, the elevation angle being shifted by 5° (beginning at 0°) for each revolution of the antenna. When a meteorological formation is acquired, its range should be read from the PPI scale marks and the appropriate sweep scale switched in. A sharp image of the meteorological object is achieved by using the "Intensity" and "Amplification" controls, and its class is determined (thunderstorm cell, shower cell, or continuous precipitation).

The specific criteria of the echo are used to classify the meteorological formations. Echos from thunderstorms and showers have a cell-type structure; individual transverse cells can extend several kilometers. The echo from thunderstorm and shower cells has a large vertical spread (more than 4 km.) and is quite powerful; thus it can be tracked easily on a type A indicator as well as a PPI.

An experienced operator can distinguish the echo of a thunderstorm from that of shower cells by the more powerful reflected signals (above 50 db.) when the vertical spread of the echo extends above the altitude of the -22° isotherm and when the distance to the target is more than 150 km.

The echo from areas of continuous precipitation is characterized by a homogeneous picture of a large area, small vertical spread (less than 4 km.), and low power. Moreover, on the RHI this echo may appear as a bright band (the melting level) and have little variability (in time and space).

The vertical dispersion of the echo is studied as follows. After the location of a meteorological formation is determined, the antenna is stopped on the azimuth of the target (its center). The antenna then scans (automatically) along the angle of elevation from -1° to +105°.

The vertical spread of the echo is observed on the RHI (up to a range of 40 km.) as both channels I and II are used simultaneously. A vertical radar cross section of the meteorological formation is thus obtained.

The horizontal dispersion of the echo can be tracked on the PPI with the 0-100-km. scale. The antenna is set on panoramic scan at the angle of elevation at which the greatest surfaces of the echo can be observed.

Operational documentation of the dispersion pattern is obtained by laying a transparent display on the RHI screen and outlining the observed pattern at the 20-40-km. scale.

Nonoperational documentation of the echo during synoptic time periods is made by photographing it from the RHI screen.

Thunderstorm cells, shower cells, and continuous precipitation are then observed on the PPI and the speed and direction of their movements determined.

Since meteorological formations can break up with time and new ones form in their place, it is recommended that the PPI be observed continuously to avert error in determining the speed and direction of these targets.

Upper and lower cloud boundaries are of particular interest to the weather forecaster and the airport flight director.

It should be recalled that every radar station has a so-called blind zone, which depends on the duration of the sounding pulse, t_p, and the location of the station. Cloud-system boundaries can thus be determined from any specific altitude, which is called the critical altitude for a particular station. Channels I and II are used in measuring the upper boundaries of all clouds as well as the lower boundary of clouds in the upper and middle layers. Precision in measuring the lower boundary of low clouds is reduced because of the presence of images from local objects on the indicator.

One of two methods is used for measuring the cloud boundaries: 1) when the antenna is scanning along the elevation angle from $-1°$ to $+105°$; 2) when the antenna is set at a specific vertical angle (β) and remains fixed during the vertical sounding.

The slant range to the clouds (R_s) is established from the scale marks on the RHI, and their altitude is found from Formula (8.1),

$$H = R_s \sin \beta$$

Measurement of the altitude of the lower boundary of clouds in the lower layer is somewhat complicated. When the echo from these clouds does not reach the ground on the RHI, slant sounding is used (the second method). Here only channel I operates, and the location of the measurement is read from the PPI and the slant range from the RHI. The altitude is determined from Formula (8.1).

It is practically impossible to determine the lower boundary of clouds when precipitation is falling from them, since in this case the echo begins from the ground.

Single-frame photography is used in determining cloud boundaries, just as in observing thunderstorm cells and shower cells.

Figs. 10.11, 10.12, and 10.13 show types of radio echos from clouds of various forms in the lower, middle, and upper layers. A brief description of the echo from different clouds as observed on MRS indicators is presented below.

1. Stratus (St) clouds appear on the RHI as a narrow unbroken band. The vertical power of the echo on the scale marks is 0.2 to 0.8 km. When light rain is falling from the clouds, the echo extends from the surface of the earth. The lower boundary of the clouds is 0.1-1.5 km.

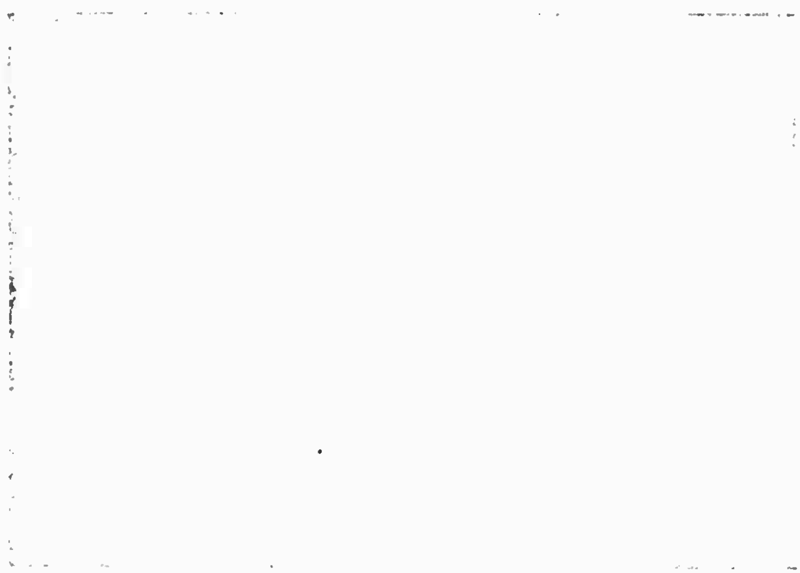

Fig. 10.11. Echos from Ac, Cb, and Cc clouds

2. An echo in the form of a narrow unbroken band, sometimes cell-like in structure, is characteristic of stratocumulus (Sc) clouds.

3. Nimbostratus (Ns) clouds with continuous precipitation (rain or snow) appear on the indicator as a spot extending from the ground to an altitude of 2-3 km.

Fig. 10.12. Echo from Nimbostratus (Ns) clouds with altocumulus (Ac) clouds during the warm half of the year

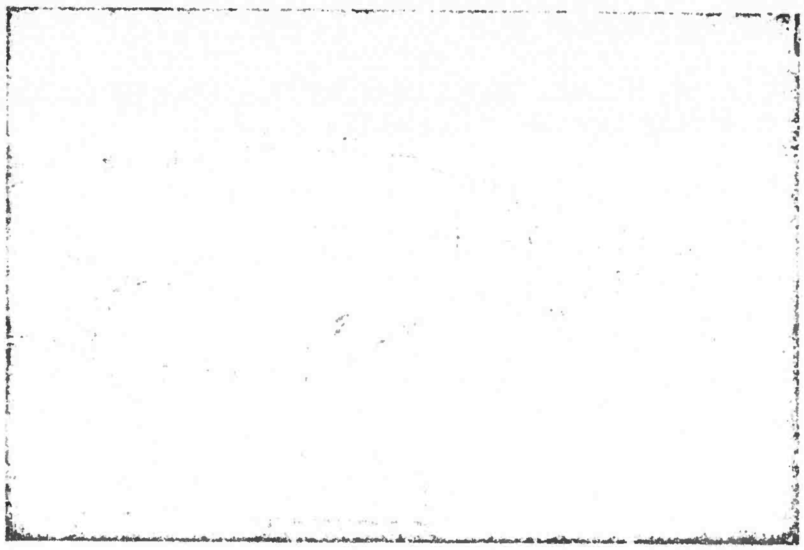

Fig. 10.13. Echo from Cb convective clouds during the warm half of the year

4. Altostratus (As) and altocumulus (Ac) clouds can be distinguished only from the pattern of the echo. The As echo is an unbroken band and the Ac echo is a band with a cell-like structure. The vertical power of these clouds on the indicator is from hundreds of meters to several kilometers. The lower boundary is 2-5 km.

5. An echo in the form of a needle-shaped band corresponds to clouds of the cirrus (Ci), cirrostratus (Cs), and cirrocumulus (Cc) types. Their vertical power is from hundreds of meters to several kilometers. The lower boundary is 4-10 km. (depending on the time of year).

6. An echo in the form of extended vertical pillars corresponds to clouds of vertical growth.

It is impossible to precisely classify the shapes of clouds from echo patterns on the RHI when clouds of various shapes are present. In this case the average power of the reflected signal is measured and the vertical cross section of the cloud cover is used.

Test Questions

1. List the basic tactical and technical specifications of the MRL-1.

2. Draw a block diagram of the channel I transmitter and explain how the units interact.

3. What is the special feature of the operation of the preamplifier in the receiving section of the MRL?

4. What is the propose of the accumulator unit?

5. What is the reflected-signal power indicator designed to do?

6. What does the indicator unit include?

7. What are the particular problems involved in finding the height of clouds on indicator screens?

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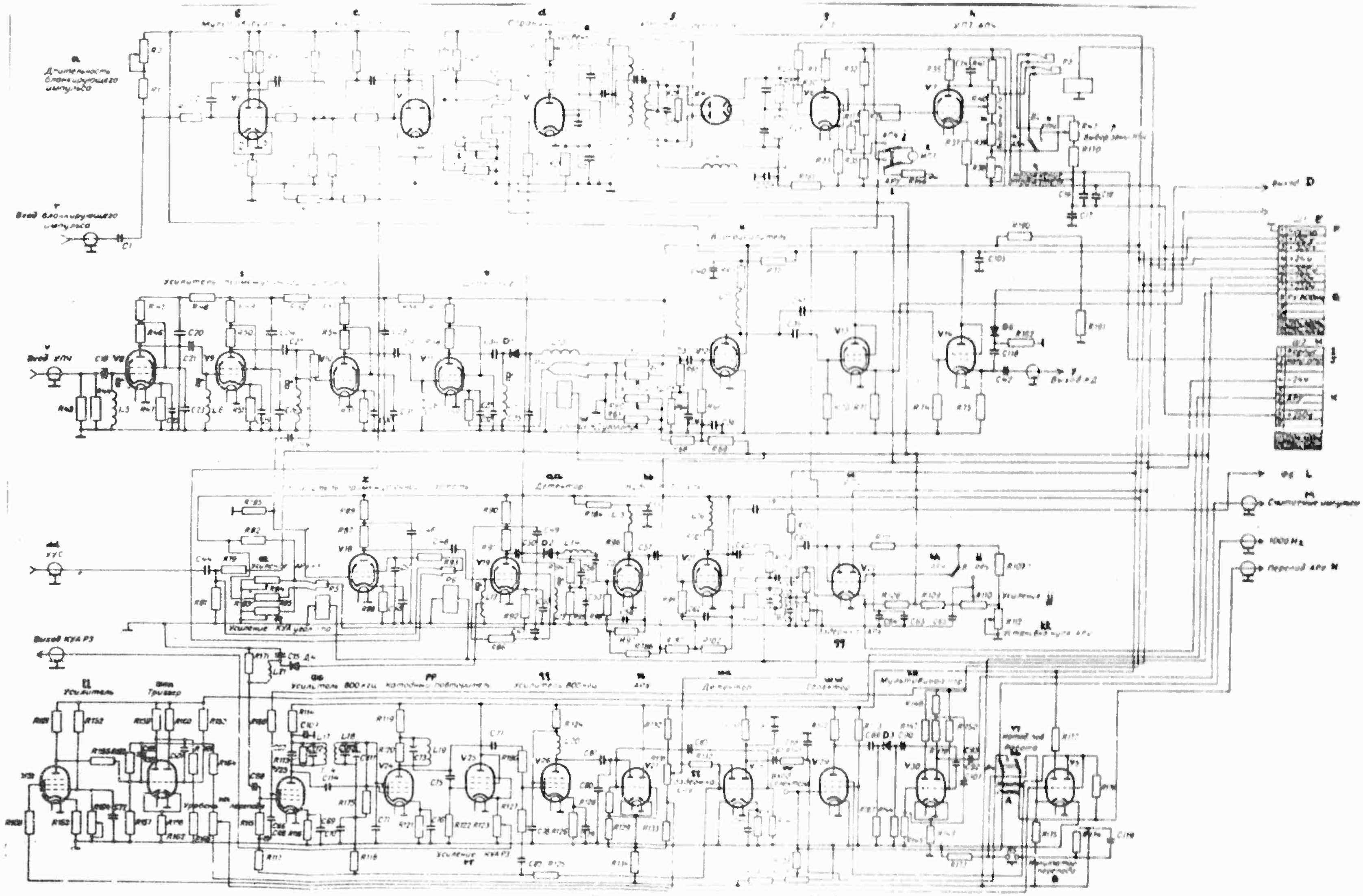

Fig. 9.15. Basic schematic of the MT-32

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